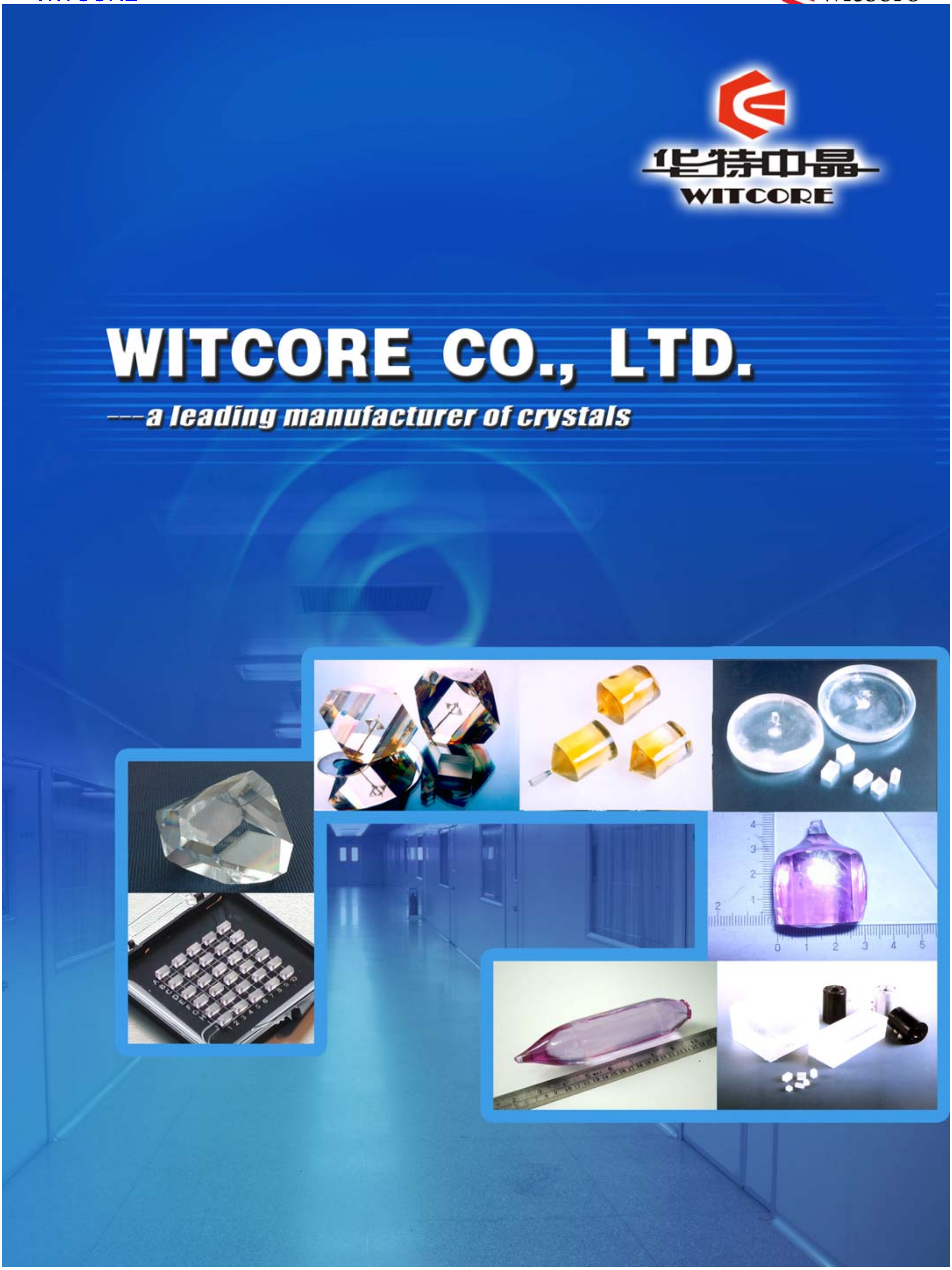

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WITCORE CO., LTD.

华特中晶
WITCORE

WITCORE CO., LTD. is located in Jinan, a famous historical and cultural city, namely the capital of Shandong provice which is called "Spring City" in China. It was founded by Coretech Crystal Co. (since 1990) and Wit Crystal, department of Shandong Shanda Wit Science & Technology Co., Ltd. (Listed company in Shenzhen Stock Exchange) at the end of 2007.

Both Coretech and Wit Crystals have evolved primarily from the National Key Laboratory --- the Institute of Crystal Material (ICM) Shandong University, one of the earliest crystal research institutes in the world. Supported by ICM,we have a competitive technical force and very strong R&D team.

The new company --- WITCORE will make full use of its share holders' advantages and competencies, our capabilities and offerings are expanded at the same time. And now, Witcore has already become one of the largest crystals supplier and manufacturer in the world.

WITCORE, a global crystals manufacturer whose customers spread all over the world including America, Europe, Australia, Korea, Japan and Taiwan, will provides you superior products and satisfactory services, with the high yields and powerful technological support.

Our whole product lines contain a wide range of non-linear optical, laser, photoelectric, pyroelectric, photorefractive crystals and the corresponding devices:

- Growting room

- ***NLO Crystals:***
  KTP (Super-KTP), KTA, RTP, LBO, BBO, KDP, DKDP
- ***Laser Crystals:***
  Nd:YAG, Nd:YVO_4, Nd:$GdVO_4$, Nd:$GdYVO_4$
  Nd:YVO_4+YVO_4-Difusion Bonded Crystal
- ***E-O & A-O Crystals:***
  $LiNbO_3$, $LitaO_3$
- ***Switch Devices:***
  DKDP-Q Switch, BBO Switch, RTP Switch, Cr:YAG Passive Switch
- ***Other Crystals Components:***
  KNSBN, SBN, YVO_4, TGS, TGG, CaF_2, MgF_2

- Polishing room

- Coating room

- Inspection room

Nonlinear Optical Crystals Application

The nonlinear optical (NLO) crystals mentioned in our catalogue are used in frequency conversion for lasers. WITCORE has a complete line of NLO crystals including KTP, BBO, KDP & DKDP, KTA, RTP, BiBO, CLBO, $LiNO_3$, $Mgo:LiNbO_3$, $LiIO_3$, etc.

Frequency Conversion

Frequency conversion processes include frequency doubling (which is a special case of sum frequency generation), sum frequency generation (SFG), differential-frequency generation (DFG) and optical parametric generation (OPG) which are demonstrated in the following equations:

Sum Frequency Generation (SFG):

$\omega_1 + \omega_2 = \omega_3$ (or $1/\lambda_1 + 1/\lambda_2 = 1/\lambda_3$ in wavelength) It combines two low-energy (or low-frequency) photons into a high-energy photon. For example:1064 nm + 532 nm -> 355 nm

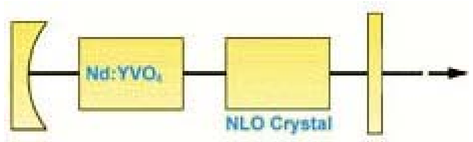
Sum Frequency Generation

Frequency Doubling

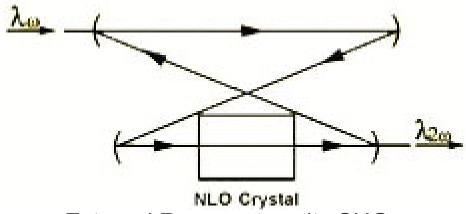
Frequency Doubling or Second Harmonic Generation (SHG) is a special case of sum frequency generation if the two input wavelengths are the same: $2\omega_1 = \omega_2$ (or$\lambda_1 = 2\lambda_2$ in wavelength). The simplest scheme for frequency doubling is extra- cavity doubling. The laser passes through the nonlinear crystal only once as shown. However, if the power density of laser is low, focused beam, intra-cavity doubling and external resonant cavity are normally used to increase the power density on the crystals, for example, for doubling of cw Nd:YAG laser and Argon Ion lasers.

Extracavity SHG

SHG With Focused Beam



Intracavity SHG



External Resonant cavity SHG

Frequency Tripling

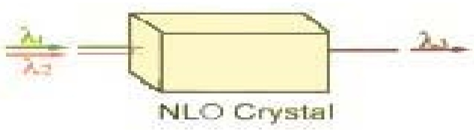
Frequency Tripling or Third Harmonic Generation (THG) is an other example of Sum Frequency Generation where, for THG of Nd:YAG laser, λ_1=1064nm, λ_2=532nm and generated wavelength λ_3=355nm. By sum frequency of fundamental wavelength and THG of a Ti:Sapphire laser in BBO crystal, it can generate wavelength as short as 193nm.

Differential-Frequency Generation (DFG):

$\omega_1 - \omega_2 = \omega_3$ (or $1/\lambda_1 - 1/\lambda_2 = 1/\lambda_3$ in wavelength)

It mixes one high energy photon with one low energy photon to get another low energy photon. For example:

532 nm - 810 nm -> 1550 nm



Differential Frequency Generation

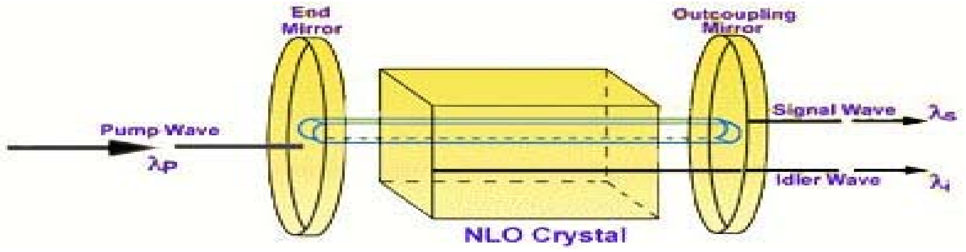
Optical Parametric Generation (OPG):

Optical Parametric Generation

$\omega_p = \omega_s + \omega_i$ (or $1/\lambda_p = 1/\lambda_s + 1/\lambda_i$ in wavelength) It splits one high-energy photon into two low-energy photons. For example:

355 nm -> 532 nm + 1064 nm

Optical Parametric Generation (OPG) is an inverse process of Sum Frequency Generation. It splits one high-frequency photon (pumping wavelength, λ_p) into two low-frequency photons (signal, λ_s, and idler wavelength, λ_i). If two mirrors are added to form a cavity as shown in following Figure, an Optical Parametric Oscillator (OPO) is established. For a fixed pump wavelength, tilting a crystal can generate an infinite number of signal and idler wavelengths. Therefore, OPO is an excellent source for generating wide tunable range coherent radiation.KTA,KTP,BBO,LBO and LiNbO3 etc. are proper crystals for OPO and Optical Parametric Amplifier (OPA) applications.



Phase-Matching

In order to obtain high conversion efficiency, the phase vectors of input beams and generated beams have to be matched:

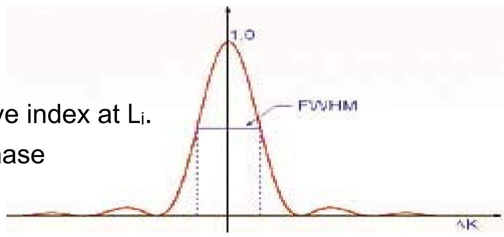
$\Delta K = k3 - k2 - k1 = 2p(n_3/L_3 - n_2/L_2 - n_1/L_1) = 0$ (For sum frequency generation)

Where ΔK is phase mismatching, k_i is phase vector at L_i and n_i is refractive index at L_i.

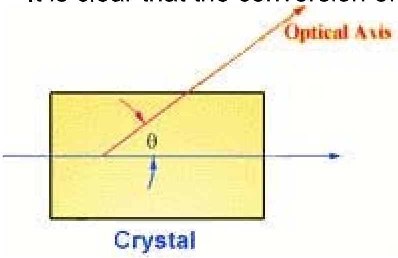
In low power case, the relationship between conversion efficiency and phase mismatching

ish ∝ (sin (¤kL)/¤kL) ^{2}

It is clear that the conversion efficiency will drop dramatically if ∆k increases.



Conversion Efficiency Vs ∆k



Critical Phase Matching

The phase-matching can be obtained by angle tilting, temperature tuning or other methods. The angle tilting is mostly used to obtain phase matching as shown in the left figure. If the angle between optical axis and beam propagation (θ) isn't equal to 90^0 or 0^0, we call it critical hase-matching (CPM).Otherwise, 90^0 non-critical phasematching (NCPM) is for θ = 90^0 and 0^0 NCPM is for θ = 0^0.

Two types of phase-matching are classified according to the polarization of lasers. If the polarizations of two input beams (for sum frequency) are parallel to each other, it is called type I phase-matching. If the polarizations are perpendicular to each other, it is called type II phase-matching.

Type I Phase Matching

Type II Phase Matching

Conversion Efficiency

How to select a NLO crystal for a frequency conversion process with a certain laser? The most important thing is to obtain high conversion efficiency. The conversion efficiency has the following relationship with the effective nonlinear coefficient (d_{eff}), the crystal length (L), the input power density (P) and the phase mismatching (¤k):

∝ PL^2(d_{eff} sin(¤kL)/ ¤kL) ^{2}

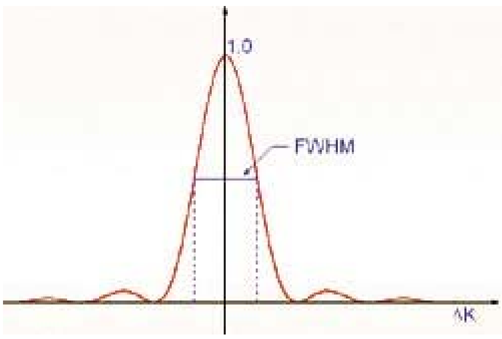
In general, higher power density, longer crystal length, larger nonlinear coefficients and smaller phase mismatching will result higher conversion efficiency. However, there is always some limitations coming from nonlinear crystals and lasers. For example, the d_{eff} is determined by the nonlinear crystal itself and the input power density has to be lower than the damage threshold of crystal. Therefore, it is important to select a right crystal for your applications. Table bellow we list out the laser and crystal parameters for selecting right crystals:

Parameters For NLO Crystal Selection

NLO Process	Phase-Matching Type and Angle, deff
Power or Energy, Repetition Rate	Damage Threshold Divergence
	Acceptance Angle Bandwidth
	Spectral Acceptance
Beam Size	Crystal Size, Walk-Off Angle
Pulse Width	Group Velocity Mismatching
Environment	Moisture, Temperature Acceptance

Crystal Acceptance

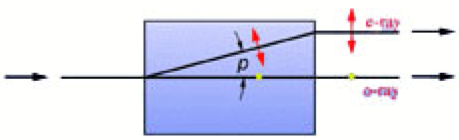
If a laser light propagates in the direction with angle △θ to phase matching direction, the conversion efficiency will reduce dramatically (see the figure right). We define the acceptance angle (△θ) as full angle at half maximum (FAHM), where θ = 0 is phase-matching direction. For example, the acceptance angle of BBO for type I frequency doubling of Nd:YAG at 1064 nm is about 1 mrad-cm. Therefore, if a Nd:YAG laser has beam divergence of 3 mrad for frequency-doubling, over half of the input power is useless. In this case, LBO may be better because of its larger acceptance angle, about 8 mrad-cm. For NCPM, the acceptance angle is normally much bigger than that for CPM, for example, 52 mrad-cm1/2 for type I NCPM LBO.



In addition, you have to consider the spectral acceptance (△λ) of crystal and the spectral bandwidth of your laser; crystal temperature acceptance (△T) and the temperature change of the environment.

Walk-Off

Due to the birefringence of NLO crystals, the extraordinary wave (ne) will experience Poynting vector walk-off. If the beam size of input laser is small, the generated beam and input beam will be separated at a walk-off angle (ρ) in the crystal and it will cause low conversion efficiency. Therefore, for focused beam or intracavity doubling, the walk-off is a main limitation to high conversion efficiency.



Group Velocity Mismatching

For frequency conversion of ultra fast lasers such as Ti:Sapphire and Dye lasers with femtosecond (fs) pulse width, the main concern is fs pulse broadening induced by group velocity mismatching (GVM)) or group velocity dispersion of NLO crystal. In order to keep efficient frequency conversion without significant pulse broadening, the suggested thickness (LGVM) of crystals is less than Pulse Width divides GVM. For frequency doubling of a Ti:Sapphire laser at 800 nm, for example, the inverse group velocities (1/VG) of BBO are respectively 1/VG = 56.09 ps/cm at 800 nm and 1/VG = 58.01 ps/cm at 400nm and GVM = 1.92 ps/cm. That means that an 1 mm long BBO crystal will make 192 fs separation between the pulses at two wavelengths. Therefore, for an 100 fs Ti:Sapphire laser, we normally recommend a 0.5mm long BBO crystal (with 96 fs separation) in order to obtain high efficiency without dramatic pulse broadening.

Potassium Titanyl Phosphate (KTiOPO4 or KTP)

KTiOPO4 (KTP) is an excellent nonlinear optical material and has been extensively used in frequency doubling of IR lasers. The 1064nm SHG conversion efficiency was reported high up to 80%. It has a lot of excellent properties such as high nonlinear optical coefficient (about 15 times KDP crystal), high Electro-Optic coefficient, low dielectric constant, high thermal conductivity (2 times that of BNN crystal). In addition, KTP crystal is moisture free and mechanically stable. It has minimum mismatch gradient, super-polished optical surface and no decomposition below 900℃.

At 2000 **WITCORE** have first developed the high-quality Super-KTP(S-KTP). Its damage threshold is more than normal KTP.

Applications:

◇Frequency Doubling (SHG) of Nd-doped Lasers for Green/Red Light Generation.
◇Frequency Mixing (SFM) of Nd Laser and Diode Laser for Blue Light Generation .
◇Parametric Sources (OPG, OPA and OPO) for 0.6um-4.5um Tunable output.
◇E-O Modulators, Optical Switches, Directional Couplers.
◇Optical Waveguides for Integrated NLO and E-O Devices, etc.
◇PPKTP for device engineering etc.

WITCORE'S warranty:

◇Standard size of KTP crystals for DPSS application;
◇AR-Coating, Mounting and Re-polishing Service;
◇Mass Production to Support Industrial and Commercial Applications;
◇Strict Quality Control;
◇Free Technical Support;
◇1 - 3 Weeks Delivery ;
◇Attractive Price and quantity discount;

specifications :	
Dimension tolerance:	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 10 arc sec.
Perpendicularity:	better than 5 arc min
Angle tolerance:	△q < 0.5°,△f < 0.5°
AR coating:	dual band AR coating at 1064/532 nm for both faces
residual reflectivity:	R1064<0.1% ,R532<0.2%
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than l/4 @ 633nm
Homogenity:	$\delta \approx 10^{-6/cm}$

Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Application	Coating
KPS2203	2*2*3mm	SHG@1064nm	AR/AR，AR/HR
KPS22 05	2*2*5mm	SHG@1064nm	AR/AR，AR/HR
KPS2210	2*2*10mm	SHG@1064nm	AR/AR
KPS3305	3*3*5mm	SHG@1064nm	AR/AR
KPS3310	3*3*10mm	SHG@1064nm	AR/AR
KPS4405	4*4*5mm	SHG@1064nm	AR/AR
KPS4410	4*4*10mm	SHG@1064nm	AR/AR
KPS5506	5*5*6mm	SHG@1064nm	AR/AR
KPS5510	5*5*10mm	SHG@1064nm	AR/AR，AR/HR
KPS6605	6*6*5mm	SHG@1064nm	AR/AR
KPS7705	7*7*5mm	SHG@1064nm	AR/AR
KPS8806	8*8*6mm	SHG@1064nm	AR/AR
KPS9907	9*9*7mm	SHG@1064nm	AR/AR
KPS1106	10*10*5mm	SHG@1064nm	AR/AR
KPO5520	5*5*20mm	NCPM OPO for 1064nm	AR/AR
KPO7715	7*7*15nm	CPM OPO for 1064nm	
KPO7720	7*7*20mm	NCPM OPO for 1064nm	AR/AR@1064&1570nm

AR Coating: AR@1064nm&532nm; HR Coating: HR@1064nm&HT@532nm
KTP crystals offered as custom required

Properties of KTP:

Physical and Chemical Properties:	Optical properties:	Nonlinear properties:
Crystal structure: orthorhombic Point group: mm2 Lattice constants a = 12.814 Å b = 6.404 Å c = 10.615 Å Temperature of decomposition: ~1150 °C Density: 3.17 g/cm^3 Mohs hardness: ~ 5 Transition temperature: 936 °C	Transmitting range: 350~4500 nm Refractive indices: at 1064 nm at 532 nm n_x = 1.7400 n_x = 1.7787 n_y = 1.7469 n_y = 1.7924 n_z = 1.8304 n_z = 1.8873 Therm-optic coefficients: dnx/dT = 1.1 x 10-5 (K)$^{-1}$ $dn_y/dT = 1.3 \times 10^{-5}$ (K)$^{-1}$ $dn_z/dT = 1.6 \times 10^{-5}$ (K)$^{-1}$	Phase matching range: 497 – 1800 nm Nonlinear Coefficients: d15= ±6.1 pm/V d24= ±7.6 pm/V d31 = ±6.5 pm/V d32 = ±5 pm/V d33= ±13.7 pm/V Electro-optic coefficients: Y_{nm}(pm/V) Low freq Y_{nm}(pm/V) High freq r_{13} 9.5 8.8 r_{23} 15.7 13.8 r_{33} 36.3 35.0 r_{42} 9.3 8.8 r_{51} 7.3 6.9

Thermal expansion coefficients: a_1 = 11 x 10^{-6} °C^{-1} a_2 = 9 x 10^{-6} °C^{-1} a_3 = 0.6 x 10^{-6} °C^{-1} Color: colorless Specific heat: 0.1737 cal/g°C Thermal Conductivity: 0.13w/cm/°C Electrical conductivity: 3.5x10^{-8}s/cm(c-axis,22°C,1kz)	Sellmeier equations: n_x^2= 2.10468 + 0.89342λ^2 /(λ^2-0.04438)-0.01036λ^2 n_y^2=2.14559+0.87629λ /(λ^2-0.0485)-0.01173λ^2 n_z^2 = 1.9446 + 1.3617λ^2 / (λ^2-0.047)-0.01491λ^2	**Type II SHG of a Nd: Laser at 1064nm:** PM angle: θ=90°, φ=23.5° Effective coefficient: d_{eff}≈8.3xd_{36}(KDP) Angular acceptance: D_θ= 75 mrad D_φ= 18 mrad Temperature acceptance: 25 °Cxcm Spectral acceptance: 5.6 Å xcm Walk-off angle: 1 mrad Optical damage threshold: >500MW/cm^2@1064nm,10ns,10HZ

Main Applications

KTiOPO4 (KTP) is an excellent nonlinear optical material and has been extensively used in frequency doubling of IR lasers. The 1064nm SHG conversion efficiency was reported high up to 80%. It has a lot of excellent properties such as high nonlinear optical coefficient (about 15 times KDP crystal), high Electro-Optic coefficient, low dielectric constant, high thermal conductivity (2 times that of BNN crystal). In addition, KTP crystal is moisture free and mechanically stable. It has minimum mismatch gradient,super-polished optical surface and no decomposition below 900℃.

I. SHG and SFG of Nd:Lasers

For nearly several decades, nonlinear optical frequency conversion techniques have been widely used for extending the utility of existing lasers. Generation of green laser radiation through second-harmonic generation (SHG) in near-infrared solid-state lasers is of particular interest for medical, industry, military, and science research.

KTP is a widely used material for frequency doubling Nd:YAG lasers and other Nd-doped lasers systems near 1064nm. Its large nonlinear coefficients, wide acceptance angle, and broad temperature bandwidth make KTP very attractive for intracavity and extracavity doubled of Nd: YAG and Nd:YVO4 lasers'.

KTP is also being applied successfully for intracavity mixing of 810 nm diode and 1064 nm Nd:YAG laser to generate blue light and intracavity SHG of Nd:YAG or Nd:YAP lasers at 1320 nm to produce red light. With the development of diode-pumped Nd:lasers, KTP play more and more important role in the construction of the compact visible solid-state lasers. Some typical results are listed as below:

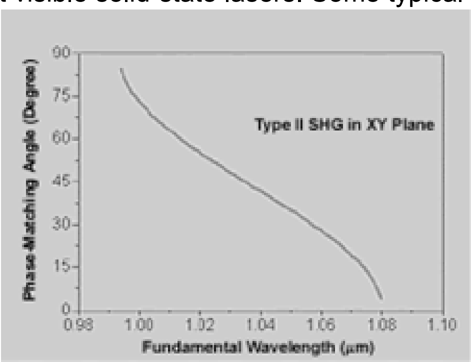


Fig. 1. Type IKTP SHG in X-Y Plane

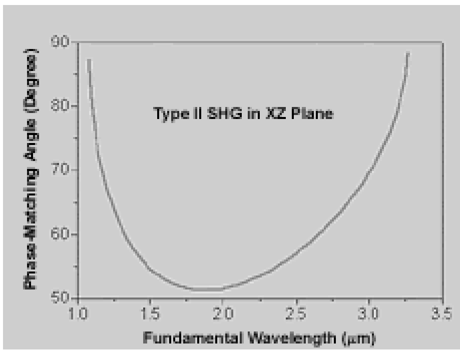


Fig. 2. Type II KTP SHG in X-Z Plane

Fig.1 shows Type II SHG phase-matching angle of KTP in X-Y plane. In X-Y plane the slope d(Δk) /dθ is small. It corresponds to quasi-angular noncritical phase matching, which ensures the advantages of a small walk off and a large acceptance angle. Otherwise, in X-Z plane the slope d(Δk) /dλ is almost zero for wavelengths in the range 1.5-2.5 um and it corresponds to quasi-wavelength noncritical phase matching, which ensures a large spectral acceptance (see Fig 2). Wavelength noncritical phase matching is highly desirable for frequency conversion of short pulses. Fig.2 shows Type II SHG phase-matching angle of KTP in X-Z plane (1.1- 3.4 um).

II. OPG, OPA and OPO

As an efficient material for OPG, OPA or OPO, KTP can be pumped by the fundamental and second harmonics of a Nd:lasers, or any other source with intermediate wavelength, such as a dye laser (near 600 nm) and Ti:Sapphire laser (near 700-1000 nm), in parametric sources for tunable output from visible(600 nm) to mid-IR (4500 nm). KTP's OPO results in stable, continuous outputs of fs pulse of 10^8 Hz repetition rate and watt average power levels in both signal and idler output. KTP's OPO pumped by a 1064 nm Nd:laser has generated more than 66% conversion efficiency for degenerately converting range 1064-2120 nm. Fig.3 and Fig.4 show KTP OPO pumped by 532 nm and 1064 nm tuning curve in XZ Plane.

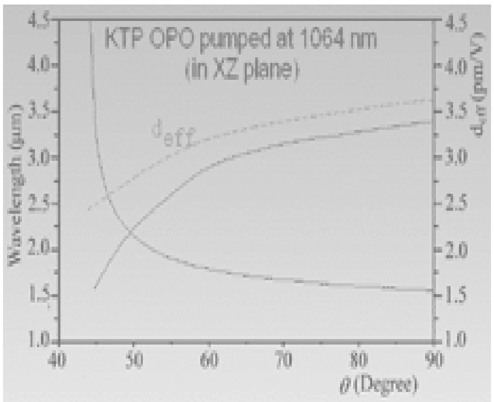


Fig.3 KTP OPO Pumped by 532 nm
Tuning Curves in X-Z Plane

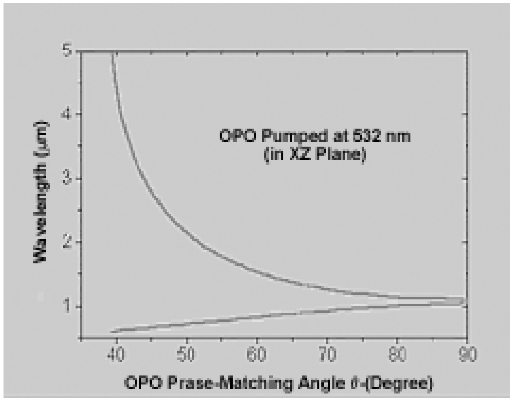


Fig.4 KTP OPO Pumped by 1064 nm
Tuning Curves in X-Z Plane

The effective application is the non-critical phase-matched (NCPM) KTP OPO/OPA pumped by the tunable lasers (as shown in Fig.5). The output can cover wavelength range from 1040 nm to 1450 um (signal) and from 2150 nm to 3200 nm (idler), by fixed the NCPM KTP crystal in X-axis, and tunes pumping wavelength (700 nm to 1000 nm). Due to the favorable NLO properties of NCPM KTP, as high as 45% conversion efficiency was obtained with narrow output bandwidth and good beam quality.

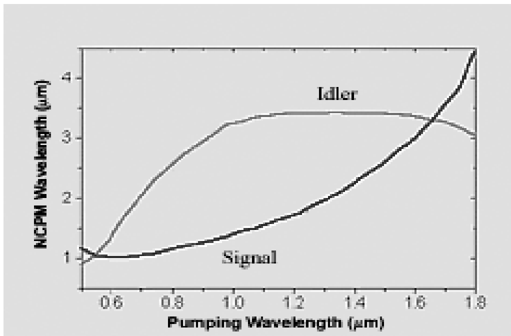


Fig.5 Type II KTP NCPM OPO

III. E-O Devices

KTP's unique NLO features and E-O dielectric properties make it extremely useful to various E-O devices. Table below gives the comparison of KTP with those commonly used E-O modulator materials.

Electro-Optic Modulator Materials

			Phase			Amplitude		
Materials	e	n	r pm/V	K $10^{-6}/^oC$	n^7r^2/Σ $(pm/V)^2$	r pm/V	k $10^{-6}/^oC$	n^7r^2/Σ $(pm/V)^2$
KTP	15.40	1.86	35.0	31	6130	270	11.7	3650

KD*P	48.0	1.47	24.0	9	178	24.0	8	178
$LiNbO_3$	27.9	2.20	28.8	82	7410	20.1	42	3500
$LiIO_3$	5.9	1.74	6.4	24	335	1.23	15	124

With these properties combined with wide optical bandwidth (>15GHz), low loss, high damage threshold, thermal and mechanical stability, KTP can be expected to replace a considerable volume of $LiNbO_3$ crystals as E-O modulators, especially for mode-locking diode laser pumped Nd:YAG \ Nd:YVO4 and Nd:YLF lasers as well as Ti:Sapphire and $Cr:LiSrAlF_6$ lasers.

IV. Optical Waveguides

On low optical absorption and high damage threshold, the low optical loss waveguide fabricated by ion-exchanged method on KTP substrate, has created novel applications of integrated optics. Following table shows the comparison of KTP with other optical waveguide materials.

Type II SHG conversion efficiency of above 20%/W/cm^2 was obtained by balanced phase matching, in which the phase mismatch from one was balanced against a phase mismatch of opposite sign from a second section. Furthermore, segmented KTP waveguides have been applied to type I quasi-phase-matchable SHG of 760-960 nm for tunable Ti:Sapphire laser and directly doubled diode laser for 400-430 nm output. Conversion efficiency in excess of 100%/W/cm^2 has been obtained.

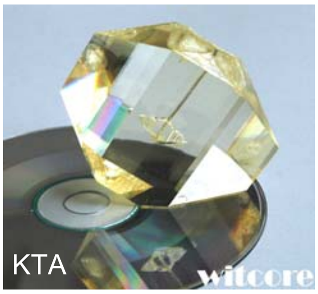
As large as 40x40x1 mm KTP with Z-cut or both surfaces polished for waveguide applications can be provided by **WITCORE**. Other sizes of KTP available upon request.

Electro-Optic Waveguide Materials

Materials	r (pm/V)	n	$\Sigma eff\ (\Sigma 11\ \Sigma 33)^{1/2}$	$n^3\gamma/\Sigma eff$(pm/V)
KTP	35	1.86	13	17.3
$KNbO_3$	25	2.17	30	9.2
$LiNbO_3$	29	2.20	37	8.3
$Ba_2NaNb_5O_{15}$	56	2.22	86	7.1
SBN(75)	56-1340	2.22	119-3400	5.1-0.14
GaAS	1.2	3.60	14	4.0
$BaTiO_3$	28	2.36	373	1.0

KTiAsO4 Crystal

Applications and Advantages:



◇an excellent NLO crystal developed mainly for Optical Parametric Oscillation (OPO)
◇Large non linear coefficients ,broad angular and temperature bandwith.
◇low dielectric constants, low ionic conductivities .
◇Lower absorption in the 3-4 μm spectrum range than KTP.
◇Resistant to high intensity laser radiation.
◇Frequency doubling (SHG @1083nm-3789nm)
◇Sum and Difference Frequency Generation (SFG)/(DFG)
◇Electro-Optical Q-switch and modulation .

WITCORE's specifications of KTA :	
Dimension tolerance:	±0.1mm
Flatness:	$\lambda/8$ @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec.
Perpendicularity:	better than 15 arc min
Angle tolerance:	< +/-0.5°
AR coating:	AR coatings
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than $\lambda/8$ @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Application	Coating
KAO3315	3*3*15mm	SFG	AR Coating
KAO7715	7*7*15mm	CPM for OPO	AR Coating
KAO6620	6*6*20mm	NCPM for OPO	AR Coating
Other KTA crystals components offered as custom required			

Physical and Chemical Properties:

Crystal Structure	Orthorhombic,pna21,mm^2
Lattice Parameters	a=1.312nm,b=0.656nm, c=1.0798nm,
Density	3.45 g/cm^3
Melting Point	1130±5°C
Ferroeletrictransition temperature (°C)	880
Ionic conductivity (room temperature,10kHz), s/cm	0.7-3.4 x 10^6

Absorption coefficient @1064nm	<0.1%/cm @ 1064 nm <0.1%/ cm @ 1533 nm <5%/cm @ 3475 nm
Hygroscopic susceptibility	No
Dielectric constant:	Σ^{33}=42
Thermal conductivity (mw/cm°C)	k1=18,k2=19,k3=21

Optical Properties:

Transmitting range:	0.35-5.3um				
Refractive indices(@ 1064 nm):	nx=1.782				
	ny=1.790,				
	nz=1.868,				
Sellmeier equations: Ni^2=Ai+Biλ^2/(λ^2-Ci^2)-Diλ^2	index	A	B	C	D
	Nx	1.90713	1.23522	0.19692	0.01025
	Ny	2.15912	1.00099	0.21844	0.01096
	Nz	2.14768	1.29559	0.22719	0.01436

Phase matching range(nm):	1075-1134nm
NCPM Angle	θ=90 φ=0
Wavelength	Pump: 1064 nm Signal: 1533 nm Idler: 3475 nm
Nonlinear Coefficients: (pm/v)	d15 =2.3
	d24 =3.2
	d31 =2.8
	d32 =4.2
	d33 =16.2
Electro-optic coefficients(low frequency, pm/v):	r13=11.5
	r23=15.4
	r33=37.5
damage threshold(10 ns pulse):	at 1064 nm
	15J/cm^2

Rubidium Titanyl Phosphate (RTiOPO4 or RTP) Crystal

Applications and Advantages:

◇High repetition rate for electro optical applications;
◇High Damage Threshold, low Insertion Loss
◇No piezo-electric ring effect;
◇Non-hygroscopic
◇High Extinction and Contrast Ratio

WITCORE 's specifications of RTP :

Dimension tolerance:	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec.
Perpendicularity:	better than 15 arc min
Angle tolerance:	< +/-0.5°
AR coating:	AR coatings
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than λ/8 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Application	Coating
RPS2205	2*2*5mm	For SHG	AR Coating
RPS3305	3*3*5mm	For SHG	AR Coating
RPE3310	3*3*10mm	For E-O switch	AR Coating
RPE4410	4*4*10mm	For E-O switch	AR Coating
Other RTP crystals components offered as custom required			

Physical and Chemical Properties:

Crystal Structure	Orthorhombic,
Lattice Parameters	a = 12.96 A°,b = 10.56 A,c = 6.49A°
Density	3.6 g/cm3
Melting Point	~ 1000 °C
Ferroeletric transition temperature	~810°C
Mohs Hardness	~5
Thermal Expansion Coefficients,/°C	a1=1.01x10^-5, a2=1.37x10^-5, a3=-4.17x10^-6
Hygroscopic Susceptibility	No

Dielectric Constant	Eeff = 13.0
Color	Colorless
Ionic conductivity (room temperature, 10kHz)	10^-8 S/cm

Optical properties:

Transmitting range:	350~4500 nm				
Sellmeier equations: Ni^2=Ai+Biλ^2/(λ^2-Ci^2)-Diλ^2	index	A	B	C	D
	Nx	2.15559	0.93307	0.20994	01452
	Ny	2.38494	0.73603	0.23891	01583
	Nz	2.27723	1.11030	0.23454	01995
Absorption coefficient:	< 0.05 % / cm @ 1064 nm < 4 % /cm @ 532 nm				

Nonlinear properties:

Nonlinear properties:	d15 = 2.0 pm/V	
	d24 = 3.6 pm/V	
	d31 = 2.0 pm/V	
	d32 = 3.6 pm/V	
	d33 = 8.3 pm/V	
Electro-optic coefficients:(pm/V)	X cut Low frequency	Y cut Low frequency
r13	10.6	
r23	12.5	
r33	35	3 8.5
Static Half Wave Voltage @1064nm:	1445 V for a pair of 4x4x10mm	
	1,600 V for a pair of 4x4x20mm	
	1,700 V for a pair of 6x6x7mm	
	2,400 V for a pair of 6x6x20 mm	
Damage Threshold:10 nsec pulse	> 600 MW/cm2 @ 1064 nm,	

Beta Barium Borate (β-BaB_2O_4 or BBO)

Applications:

◇Second, third, fourth and fifth harmonic generation
◇Frequency double, tripling and mixing of Dye and Ti :Sapphire lasers
◇Optical Parametric amplifiers(OPA) and optical parametric oscillators(OPO)

Advantages:

◇Broad phase-matching wavelength range from 409.6 nm to 3500 nm;
◇Wide transmission region from 190 nm to 3500 nm;
◇Large effective SHG coefficient about 6 times greater than that of KDP crysta
◇High damage threshold of 10 GW/cm2 for 100 ps pulse-width at 1064 nm;
◇High optical homogeneity with Δn ~ 10-6/cm;
◇Wide temperature-bandwidth of about 55°C.(for type I SHG 1064nm)
◇Good Mechanical and physical properties

WITCORE'S warranty:

◇Standard size of BBO crystal for application;
◇Strict Quality Control;
◇1 - 3 Weeks Delivery ;
◇Attractive Price and quantity discount;
◇Free Technical Support;
◇P-coatings, AR-Coating, Mounting and Re-polishing Service;
◇Mass Production to Support Industrial and Commercial Applications;

WITCORE's specifications of BBO:	
Dimension tolerance:	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec.
Perpendicularity:	better than 15 arc min
Angle tolerance:	<+/-0.5°
AR coating:	P-coating, AR or DBAR coatings
residual reflectivity:	R1064<0.2% ,R532<0.5% R355<0.5%,R266<0.5%
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than λ/8 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Application	Coating
BOH4407	4*4*7mm	S/T/FHG@1064nm,	AR/AR,
BOS8407	8*4*7mm	SHG for Dye laser,	P-Coating,

BOS5501	5*5*1mm	SHG@800nm,	P-Coating,
BOS550.5	5*5*0.5mm	SHG@800nm,	p-Coating,
BOO4415	4*4*12mm	OPO,	AR/AR

Basic Properties

Physical and Chemical properties:

Crystal structure:
Trigonal, space group R3c

Lattice parameters:
a=b=1.253nm, c=1.272nm, Z=6

Melting point: 1095±5°C

Phase transition temperature925±5°C

Temperature stability:8 x KDP

FWHM of phase matched SHG
55°C

Mohs hardness 4.5 -5

Density: 3.85 g/cm^3

Absorption coefficient @1064nm
<0.1%/cm^3

Hygroscopic susceptibility low

Resistivity >1011 ohm-cm

Relative dielectric constant
Σs11/Σo:6.7, Σs33/Σo:8.1,Tan δ<0.001 **Thermal expansion coefficients**
(25°-900°C) a, 4 x 10-6/K; c, 36 x 10-6/K

Thermal conductivity
∞c, 1.2 W/m/K; //c, 1.6 W/m/K

Linear Optical Properties:

Transparency range:
189-3500 nm

Refractive indices:
@1064nm
n_e=1.5425, n_o=1.6551
@532nm
n_e = 1.5555,n_o=1.6749
@266nm
n_e = 1.6146, n_o = 1.7571

Therm-optic coefficients:
$dn_o/dT = -9.3 \times 10^{-6}/°C$
$dn_e/dT = -16.6 \times 10^{-6}/°C$

Sellmeier equations: (λ in μm)
$n_o^2=2.7359+0.01878/(\lambda^2-0.01822)-0.01354\lambda^2$
$n_e^2=2.3753+0.01224/(\lambda^2-0.01667)-0.01516\lambda^2$

Nonlinear Optical Properties:

Phase-matchable output wavelengths:
189 - 1750 nm

NLO coefficients:
$d_{11} = 5.8 \times d_{36}$(KDP)
$d_{31} = 0.05 \times d_{11}$
$d_{22} < 0.05 \times d_{11}$

Electro-optic coefficients:
γ_{11} = 2.7 pm/V, γ_{22}, $\gamma_{31} < 0.1\gamma_{11}$

Half-wave voltage:
48 KV (at 1064 nm)

Damage threshold:
@1064nm
5GW/cm^2(10ns);10GW/cm^2 (1.3 ns)
@532nm
1GW/cm^2(10ns); 7GW/cm^2 (250ps)

Beta-Barium Borate-Applications

Applications in Nd:YAG Lasers

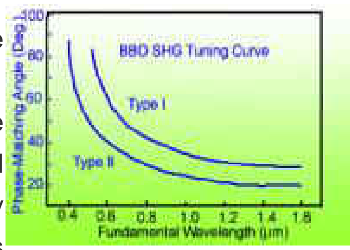
BBO is an efficient NLO crystal for second, third and fourth harmonic generations of Nd:YAG lasers, and the favourite NLO crystal which can be used to produce the fifth harmonic generation (5HG) at 213nm.

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 and KD*P crystals in a Spectra-Physics DCR-2 Nd:YAG laser, and the basic nonlinear optical properties from SHG to 5HG are listed inTable 1 and Table 2, respectively.

Harmonic generations using BBO and KD*P crystals					
Crystals	Fundamental(mJ)	SHG(mJ)	THG(mJ)	4HG(mJ)	5HG(mJ)
BBO	220	105	39	18.5	5
BBO	600	350	140	70	20
KD*P	600	270	112.5	45	/

Relevant NLO properties for type I BBO crystals				
	SHG(mJ)	THG(mJ)	4HG(mJ)	5HG(mJ)
Effective NLO Coefficients(d33(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
Temperature Acceptance (¡æ)	51	16	4	/

BBO is an efficient NLO crystal for intracavity SHG of high power Nd:YAG lasers. For intracavity SHG of an acousto-optic Q-switched Nd:YAG laser, more than 100W average power at 532nm was generated.



BBO is also an excellent crystal to be applied to frequency-double, -triple and -quadruple the high power acousto-optic and electro-optic Q-switched and mode-locked Nd:YAG and Nd:YLF lasers. More than 4W UV output at 355nm and 2W output at 266nm are stably generated. Using specially designed optical system, conversion efficiency >50% is obtained for frequency doubling 532nm.

In addition, greater than 1W cw output at 266nm was produced from a BBO in an external resonant cavity.

APPLICATIONS IN TUNABLE LASERS

1. Dye Lasers

Efficient UV output (205 - 310nm) with a SHG efficiency of over 10% at wavelength of >=206nm has been obtained in type I BBO, and 36% conversion efficiency was achieved for the XeCl-laser and Nd:YAG laser pumped Dye lasers (e.g. Lambda Physik, models FL 3000 and LPD 3000) with the power of 150KW. The conversion efficiency is about 4 - 6 times higher than that of ADP. The shortest SHG wavelength of 204.97nm with efficiency of about 1% has been generated.

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

2. Ultrafast Laser

Frequency-doubling and -tripling of ultra-fast pulse lasers, for example, femtosecond (fs) Ti:Sapphire lasers, are the applications in which BBO shows superior properties compared with KDP and ADP crystals. A laser pulse as short as 2fs can be efficiently frequency-doubled with an ultra thin BBO by considering both phase-velocity and group-velocity matching.

3. Ti:Sapphire and Alexandrite Lasers

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

More than 50% of SHG conversion efficiency in a Ti:Sapphire laser has been obtained. High conversion efficiencies were also obtained for THG and 4HG of Ti:Sapphire lasers.

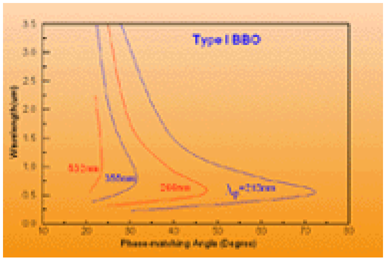
4. Argon Ion and Copper-Vapor Lasers

BBO is most suitable NLO crystals for directly frequency doubling wavelength less than 532nm to generate UV output. By employing the intracavity frequency-doubling technique in an Argon Ion laser with all lines output power of 2W, maximum 33 mW 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.

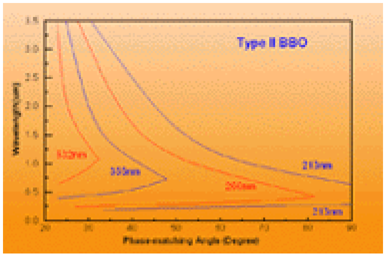
Up to 230mW average power in UV at 255.3nm with maximum 8.9% conversion efficiency has been achieved for the SHG of Copper-Vapor laser at 510.6nm.

OPO and OPA

BBO's OPO and OPA are the powerful tool for generating the widely tunable coherent radiation from UV to IR. The tuning angles of type I and type II BBO OPO and OPA have been calculated and shown as following respectively.



Type I OPO Tuning Curves of BBO



Type II OPO Tuning Curves of BBO

By using BBO crystals, Spectra-Physics MOPO-700 Series OPO Systems can generate more than 100 mJ pulse energy with wavelength tunable from 400nm to > 2000 nm. The wavelength range can be further extended from 200nm to 3000 nm by using BBO or KDP crystal.

Type II BBO can be used to decrease line width near degenerate points. Line width as narrow as 0.05nm and usable conversion efficiency of 12% were obtained. However, long (>15mm) BBO should be normally used to decrease the oscillation threshold when the type II phase-matching scheme is employed.

Pumping with picosecond Nd:YAG laser at 355 nm, narrow-band (< 0.3 nm), high energy (> 200mJ) and wide tunable (400 nm to 2.0 mm) pulse have been produced by BBO's OPA. BBO's OPA, with over 50% conversion efficiency, is superior to common Dye lasers in efficiency, tunable range. It is easy to design, operate and maintain.

BBO's OPO pumped by fourth harmonic of a Nd:YAG laser (at 266nm) has been observed to cover the whole range of 330 - 1370 nm. The Nd:YAG at 266nm pumped OPO is commercially available by OPOTEK (CA, USA). The special design system is able to generate wavelength tunable from 300nm -500nm with 8mJ/pulse output power at 10Hz.

Frequency Conversion of Ultrafast Lasers

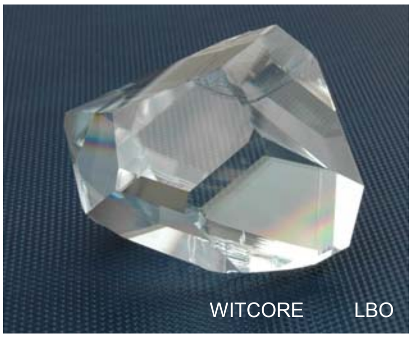
For frequency conversion of ultrafast lasers with femtosecond (fs) pulse width, the main concern is fs pulse broadening induced by group velocity mismatching (GVM) or group velocity dispersion of NLO crystal. In order to keep efficiency frequency conversion without significant pulse broadening, the suggested thickness (LGVM) of crystals is less than Pulse Width divides GVM.

Application (Type I) BBO Crystals	SHG of 700 nm	SHG of800 nm	SHG of 900 nm	THG of 700 nm	THG of 800 nm	THG of 900 nm
deff (pm/V)	1.296	1.365	1.408	0.893	1.101	1.221
GVM (ps/cm)	2.721	1.922	1.401	8.497	5.676	4.079
LGVM @ 10fs (micron)	40	50	70	10	20	30
Damage threshold@ 10fs (GW/cm^2)	20	25	30	10	15	20

Lithium Triborate or LiB_3O_5

LBO (Lithium Triborate or LiB_3O_5) is an excellent crystal which has very wide transparency, high nonlinear coupling, high damage threshold and good chemical and mechanical properties. We had grown LBO for more than 10 years and we now have much experience in it.

WITCORE's LBO is grown by an improved flux method and we could provides high quality LBO crystals for many applications.



WITCORE 's LBO is applied for:

◇High power Nd:YAG and Nd:YLF lasers for R&D and military applications.
◇Ti:Sapphire, Alexandrite and Cr:LiSAF lasers.
◇Medical and industrial Nd:YAG lasers.
◇Diode laser pumped $Nd:YVO_4$, Nd:YAG and Nd:YLF lasers.
◇Frequency-tripling (THG) of Nd:YAG and Nd:YLF lasers.
◇Optical parametric amplifiers (OPA) and oscillators (OPO) pumped by Excimer lasers and harmonics of Nd:YAG lasers.
◇Frequency doubling (SHG) and tripling (THG) of high power Nd:YAP laser at 1.34μm

WITCORE 's LBO is featured by:

◇ Broad transparency range from 160nm to 2.6 μm (SHG range from 0.55μm to 2.6 μm).
◇ Type I and type II non-critical phase-matching (NCPM) over a wide wavelength range.
◇ Relatively large effective SHG coefficient (about three times larger than that of KDP).
◇ High damage threshold (18.9 GW/cm^2 for a 1.3ns laser at 1.054μm)
◇ Wide acceptance angle and small walk-off
◇ High optical quality (homogeneity $\Delta n \approx 10^{-6}$/cm) and free of inclusion.

LBO'S Basic Properties:

Table 1. Chemical and Structural properties

Crystal Structure	Orthorhombic, Space group $Pna2_1$, Point group mm2
Lattice Parameter	a=8.4473Å, b=7.3788Å , c=5.1395Å , Z=2
Melting Point	About 834℃
Mohs Hardness	6
Density	2.47 g/cm^3
Thermal Conductivity	3.5W/m/K
Thermal Expansion Coefficient	$a_x=10.8x10^{-5}/K$, $a_y= -8.8x10^{-5}/K$, $a_z=3.4x10^{-5}/K$

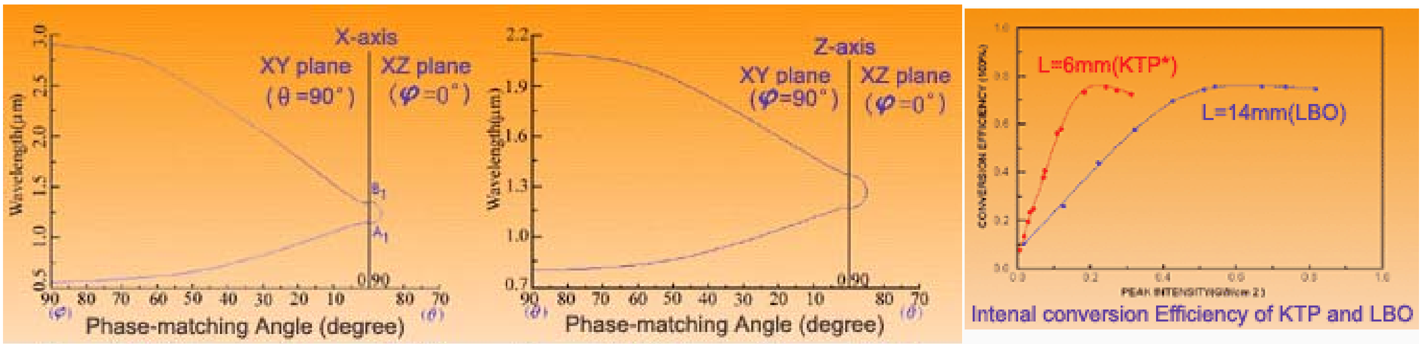
Table 2. Optical and Nonlinear Optical Properties

Transparency Range	160-2600nm
SHG Phase Matchable Range	551 ~ 2600nm (Type I) 790-2150nm (Type II)
Therm-optic Coefficient (°C, l in μm)	$dnx/dT=-9.3X10^{-6}$ $dny/dT=-13.6X10^{-6}$ $dnz/dT=(-6.3-2.1l)X10^{-6}$
Absorption Coefficient	<0.1%/cm at 1064nm <0.3%/cm at 532nm
Angle Acceptance	6.54mrad-cm (φ, Type I,1064 SHG) 15.27mrad-cm (q, Type II,1064 SHG)
Temperature Acceptance	4.7°C-cm (Type I, 1064 SHG) 7.5°C-cm (Type II,1064 SHG)

Spectral Acceptance	1.0nm-cm (Type I, 1064 SHG) 1.3nm-cm (Type II,1064 SHG)
Walk-off Angle	0.60° (Type I 1064 SHG) 0.12° (Type II 1064 SHG)
NLO Coefficient	$d_{eff}(I)=d_{32}\cos\varphi$ (Type I in XY plane) $d_{eff}(I)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type I in XZ plane) $d_{eff}(II)=d_{31}\cos\theta$ (Type II in YZ plane) $d_{eff}(II)=d_{31}\cos^2\theta+d_{32}\sin^2\theta$ (Type II in XZ plane)
Non-vanished NLO susceptibilities	d_{31}=1.05 ± 0.09 pm/V d_{32}= -0.98 ± 0.09 pm/V d_{33}=0.05 ± 0.006 pm/V
Sellmeier Equations(λ in μm)	$n_x^2=2.454140+0.011249/(\lambda^2-0.011350)-0.014591\lambda^2-6.60\times10^{-5}\lambda^4$ $n_y^2=2.539070+0.012711/(\lambda^2-0.012523)-0.018540\lambda^2+2.0\times10^{-4}\lambda^4$ $n_z^2=2.586179+0.013099/(\lambda^2-0.011893)-0.017968\lambda^2-2.26\times10^{-4}\lambda^4$

LBO's application:

LBO is phase-matchable for SHG and THG of Nd:YAG and Nd:YLF lasers by using either type I or type II interaction. For SHG at room temperature, type I phase-matching can be reached and has maximum effective SHG coefficient in theprincipal XY and XZ planes in a wide wavelength range from 551 nm to about 3 μm. The optimum type II phase-matching falls in the principal YZ and XZ planes.



Type I SHG Tuning Curve of LBO   Type II SHG Tuning Curve of LBO   Internal SHG Conversion Efficiency

SHG conversion efficiencies of more than 70% for pulse and 30% for cw Nd:YAG lasers, and THG conversion effi-ciency of over 60% for pulse Nd:YAG laser have been observed respectively. The SHG conversion efficiency of LBO in an unstable resonator Nd:YAG laser vs the average power density in comparison with that of KTP is shown in next figure.

Applications:

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

◇Over 60 W green output is obtained by SHG of a Q-switched Nd:YAG laser in a type II, 18 mm long LBO crystal.

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

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

◇2 mJ/pulse diffraction-limited beam at 355 nm is obtained by **intracavity tripling** a Q-switched Nd:YAG laser.

◇LBO is very promising for the generation of 266 nm from Nd:YAG, Nd:YVO_4 laser because of its low absorption at 266 nm.

Non-Critical Phase-Matching(NCPM)

The **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. The SHG conversion efficiencies of more than 70% for pulse and 30% for cw Nd:YAG lasers have been obtained with good output stability and beam quality.

Type I and type II NCPM can be reached along x-axis ($\theta = 90^o$, $\varphi = 0^o$) and z-axis ($\theta = 0^o$, $\varphi = 0^o$), respectively. As shown in the figure, NCPM SHG over a broad wavelength range from 900 nm to about 1700 nm was measured. The properties of NCPM SHG of Nd:YAG laser at 1.064μm are listed in following table.

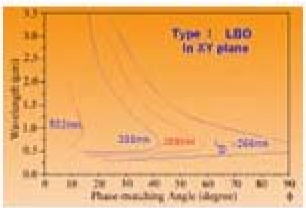
Properties of type I NCPM SHG at 1064nm	
NCPM Temperature	148°C
Acceptance Angle	52 mrad-cm$^{1/2}$
Walk-off Angle	0
Temperature Bandwidth	4°C-cm
Effective SHG Coefficient	2.69 d_{36}(KDP)

Applications:

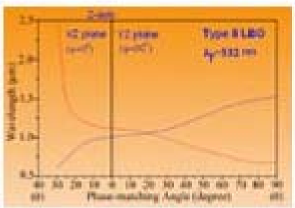
- ◇ Over 10 W and highly stable green output @ 532 nm was obtained with NCPM LBO for frequency doubling of diode pumped Nd:YVO_4 lasers. All solid state SLM, Q-switched green and UV lasers are available.
- ◇ Over 100 W green output was achieved with type II LBO for frequency doubling of Q-switched Nd:YAG laser.
- ◇ LBO can reach both temperature NCPM and spectral NCPM (very wide spectral bandwidth) at 1.3 μm.
- ◇ More than 11 W @ 532 nm was obtained by extracavity SHG of a 25 W mode-locked Nd:YAG laser. Following drawing shows the SHG output vs input power of Nd:YLF laser (76MHz, 45ps).

LBO's OPO and OPA

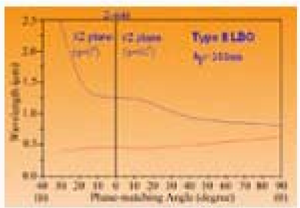
LBO is an excellent NLO crystal for the widely tunable wavelength range and high power OPO and OPA. The type I and type II OPO and OPA pumped by SHG and THG of Nd:YAG laser and XeCl excimer laser at 308 nm have been reported. The figure shows the calculated OPO tuning curves of a type I LBO pumped by SHG, THG and 4HG of Nd:YAG laser in XY plane at room temperature, and also shows the calculated OPO tuning curves of a type II LBO pumped by SHG and THG of Nd:YAG laser in YZ and XZ planes.



Type I OPO Tuning Curves of LBO



Type II OPO Tuning Curves of LBO Pumped at 532 nm



Type II OPO Tuning Curves of LBO Pumped at 355 nm

Applications

- ◇ By using 90° NCPM LBO, Spectra-Physics SPPO OPO synchronously pumped by femtosecond Ti:Sapphire laser generates < 130 fs pulse from 1.1 to 2.6 μm.
- ◇ Type I OPA pumped at 355 nm with pump-to-signal energy conversion efficiency of 30% has been reported.
- ◇ By using the NCPM technique, type I OPA pumped by SHG of Nd:YAG laser at 532 nm was also observed to cover a widely tunable range from 0.75 mm to 1.8mm by temperature-tuning from 106.5C to 148.5C.

◇ By using type II NCPM LBO as an optical parametric generator (OPG) and type I critical phase-matched BBO as an OPA, narrow linewidth (0.15 nm) and high pump-to-signal energy conversion efficiency (32.7%) were obtained when it is pumped by a 4.8 mJ, 30ps laser at 355nm. Wavelength tuning range from 482.6 to 415.9 nm is covered by increasing the temperature of LBO.

WITCORE also provides coatings for LBO:

1. Dual-band AR-coating of LBO for SHG of Nd:YAG lasers.

Low reflectance

(< 0.2% at 1.064 mm and < 0.5% at 0.532 mm);

High damage threshold

(> 500 MW/cm2 at both wavelengths);

Long durability.

2. Broad Band AR-coating for frequency doubling Ti:Sapphire laser.
3. Other coatings are available upon request.

WITCORE'S Warranty on LBO Specifications

Transmitting wavefront distortion	less than $\lambda/8$ @ 633nm
Dimension tolerance	(W± 0.1 mm) x (H± 0.1 mm) x (L + 0.2 mm/-0.1 mm)
Clear aperture	central 80% diameter
No visible scattering paths or centers when inspected by a 30 mW green laser	
Flatness	$\lambda/8$ @ 633nm
Surface Quality	1\~05 Scratch/Dig to MIL-O-13830A
Parallelism	better than 20 arc seconds
Perpendicularity	15 arc minutes
Angle tolerance	< ±0.5o, <± 0.5o
Damage threshold: 15 GW/cm^2 for a TEM_{oo} mode, 1.3 ns, 1 Hz laser at 1.064 μm 1 GW/cm^2 for a cw, mode-locked laser at 1.064 μm	
Quality warranty period	1 year under proper use

◇ Strict quality control.

◇ Large crystal with size up to 10x10x30 mm^3 and maximum length of 60 mm

◇ AR-coatings, mounts and repolishing services.

◇ Strong technical support.

◇ Mass production line to support OEM applications

◇ Unbeatable prices and special OEM discount.

◇ Fast delivery, in-stock crystals in a large quantity. (10 days for polished only, 16 days for AR-coated).

NOTE PLEASE

1.LBO has a very low susceptibility to moisture. Users are advised to provide dry conditions for both use and preservation of LBO.

2.Users are advised to cautiously protect polished surfaces of LBO.

3.**WITCORE**'s engineers can select and design the best crystal for you if parameters of your laser are provided, for example, energy per pulse, pulse width and repetition rate for a pulsed laser, power for a CW laser, laser beam diameter, mode condition, divergence, wavelength tuning range, etc.

4.For thin crystal, we could provides mounts and sealed housing.

KDP and DKDP Crystals

Potassium Dihydrogen Phosphate(KDP) and Potassium Dideuterium Phosphate(DKDP) are widely used for electro-optical modulation and frequency conversion. WITCORE's KDP and DKDP have high nonlinear coefficient and high optical damage threshold, and can be used electro-optical modulator, Q switches and shutters for high speed photography.

Applications and Advantages:

◇Electro-optical modulator, Q-switches;

◇ Second, third and fourth harmonic generation, frequency double for dye laser;

◇Shutter for high speed photography;

◇High power laser frequency conversion materials;

WITCORE 's specifications of KDP & DKDP :

Dimension tolerance:	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec.
Perpendicularity:	better than 15 arc min
Angle tolerance:	<+/- 0.5°
AR coating:	uncoatings
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than λ/8 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Application	Coating
DPS1313	13.5*13.5*15/20/30mm	For S/THG@1064nm	uncoating
DPS0505	5*5*1mm	For SHG@800nm	uncoating
DPQ1010	Dia10*27mm	For E-O switch	uncoating
DPQ1212	Dia12*27mm	For E-O Switch	uncoating.
Other KDP &DKDP crystals components offered as custom required			

Chemical formula	KH_2PO_4	KD_2PO_4
Symmetry	42m	42m
Density (g/cm^3)	2.332	2.335
Lattice parameters	a = b =7.453 Å c=6.293Å	a=b=7.469 Å c=6.976Å
Thermal expansion coefficient /K)	$\alpha_1 = \alpha_2 = 24.9 \times 10^{-6}$	$\alpha_1 = \alpha_2 = 19 \times 10^{-6}$
Thermal conductivity (W/cm /K)	-----	$K_1 = K_2 = 1.9\times10^{-2}$ $K3=2.1\times10^{-2}$
Transmission	200 ~ 1580nm	200 ~ 2150nm
Absorption (%/cm at 1064nm)	3	0.5
Curie temperature (K)	222	123
Relative dielectric constant	at 1 KHz, 25ºC	
ε^T_{11}	42	65
ε^S_{11}	44	58
ε^T_{33}	21	50
ε^S_{33}	21	48
NLO coefficient (pm/v)	0.43	0.40
Longitudinal half-wave voltage	8.8Kv (658.3nm)	3.5-4Kv (632.8nm)
SHG phase-matching angle at 1064nm		
Type Ⅰ	41º	37º
Type Ⅱ	59º	53.5º
Refractive indexes		
1064nm n_o	1.4942	1.4931
1064nm n_e	1.4603	1.4583
532nm n_o	1.5129	1.5074
532nm n_e	1.4709	1.4681
355nm n_o	1.5377	1.5257
355nm n_e	1.4867	1.4683
Sellmeier equation	Ni^2=Ai+ Bi /(λ^2-Ci^2)-Diλ^2 /（λ^2－E）	

	A	B	C	D	E

For KDP	n_o	2.2576	0.0101	0.0142	1.7623	57.8984
	n_e	2.1295	0.0097	0.0014	0.7580	127.0535
For DKDP	n_o	2.2409	0.0097	0.0156	2.2470	126.9205
	n_e	2.1260	0.0086	0.0120	0.7844	----------

Neodimium Doped Yttrium Aluminum Garnet (Nd:YAG)

Advantages:

◇High Gain, High Efficiency, Low Threshold,
◇High Optical Quality and low Loss at 1.06 mm,
◇Good Mechanical and Thermal Properties
◇Easy to operate in Q-Switch, pulsed, CW mode.

WITCORE'S warranty:

◇Standard size crystal for application;
◇Strict Quality Control;
◇1 - 3 Weeks Delivery ;
◇Attractive Price and quantity discount;
◇Mass Production to Support Industrial and Commercial Applications;

WITCORE 's specifications of Nd:YAG:	
Dimension tolerance:	diameter:<0.025 mm , Length: <0.5 mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec
Perpendicularity:	better than 5 arc min
Orientation	<111> crystalline direction, tolerance:<+/-0.5°
chamfer:	<0.1 mm @ 45deg
AR coating:	AR coating, HR Coating
residual reflectivity:	R<0.2%@1064nm, HR:R>99.8%@1064 nm,R<5%@808nm
Clear aperture:	>95% central area
Transmitting wavefront distortion:	<7mm diameter : <λ/8 per inch @ 633nm <7mm diameter :<λ/10per inch @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Doped	Coating
NYA0305	Dia3*5mm	1at %	AR/AR@946nm
NYA0360	Dia3*60mm	1at %	AR/AR@1064nm
NYA0580	Dia5*80mm	1at %	AR/AR@1064nm
NYA0680	Dia6.35*80mm	1at %	AR/AR@1064nm
NYA101001	10*10*1mm	1at %	AR/AR@1064nm
Other Nd:YAG crystals components offered as custom required			

Basic Properties:

Chemical Formula:	Nd x Y3-x Al5 O12 (x = 0.006 - 0.012)
Crystal structure:	Cubic
Lattice constant:	1.201nm
Melting point:	1970 ^{o}C
Density:	4.56g/cm^{3}
Index of refraction @ 1064nm:	1.82
Thermal Expansion Coefficient:	7.8x10^{-6} /K <111>
Thermal Conductivity (W/m/K):	14W/m/K, 20º C, 10.5W/m/K, 100º C
Mohs hardness:	8.5
Stimulated Emission Cross Section(1 at% Nd):	2.8x10^{-19} cm^{-2}
Spontaneous Fluorescence lifetime (1 at% Nd)	230 m s
Line width @ 1064 nm	0.45 nm
Photon energy @ 1064nm	1.86x10^{-19} J
Pump Wavelength	807.5nm
Polarized Emission	Unpolarized
Thermal Birefringence	High
Absorption band at pump wavelength	1nm
Loss Coefficient:	0.003 cm^{-1} @ 1064nm
Scatter losses	~ 0.002 cm^{-1} @ 1064nm

Nd:YVO_4 Crystal

Nd:YVO_4 crystal is one of the most excellent laser host materials, it is preferable for diode laser-pumped solid state laser. The crystal has these many typical 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.

Applications and Advantages:

◇Lower lasing threshold and higher slope efficiency;

◇High absorption over a wide pumping wavelength bandwidth;

◇Low dependency on pumping wavelength and tend to single mode output;

◇Large stimulated emission cross-section at lasing wavelength;

◇Preferable-polarized laser generation;

WITCORE's specifications of Nd:YVO_4 :

Dimension tolerance	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec.
Perpendicularity:	better than 15 arc min
Angle tolerance	△ < 0.5°
AR coating:	AR:R<0.2%@1064nm, R<0.5@808nm HR:R>99.8%@1064nm,R<5%@ 808nm
Clear aperture:	>90% central area
Transmitting wavefront distortion:	less than λ/8 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Doped	Coating
NY3301	3*3*1mm	1%,2%,3%	AR/AR,HR/AR
NY3302	3*3*2mm	1%	AR/AR,HR/AR
NY3305	3*3*5mm	0.5%	AR/AR,HR/AR
NY4408	4*4*8mm	0.27%	AR/AR
Other Nd:YVO4 crystals components offered as custom required.			

Basic Properties:

Crystal Structure:	Zircon Tetragonal, space group D_{4h} I4/amd a=b=7.1193, c=6.2892
Atomic Density:	1.26x1020 atoms/cm3 (Nd 1.0%)
Mohs Hardness:	Glass-like， 4.6-5
Density:	4.22g/cm3
Melting point:	1810+/-25℃
Thermal Expansion Coefficient (300K):	a a=4.43x10-6/K , a c=11.37x10-6/K
Thermal Conductivity Coefficient (300K):	//C: 52.3mW/cm/K ∞C: 51mW/cm/ K

Optical Properties:

Transmission range	400-3800nm	
Lasing wavelength:	1064nm -1342nm	
Refractive indexes	n_o	n_e
1064nm	1.9573	2.1652
808nm	1.9721	2.1858
532nm	2.0210	2.2560
Thermal optical coefficient (300K):	$dn_o/dT=8.5\times 10^{-6}/K$; $dn_e/dT=2.9\times 10^{-6}/K$	
Sellmeier Equation (for pure YVO4 crystals) :	$n_o^2 =3.77834+0.069736/(\lambda^2-0.04724)-0.0108133\lambda$ $n_e^2=4.59905+0.110534/(\lambda^2 -0.04813)-0.0122676\lambda$	
Stimulated emission cross-section:	$25\times10^{-19}cm^2$@1064.3nm, $6\times10^{-19}cm^2$@1342nm	
Fluorescent lifetime:	90us	
Absorption coefficient:	$31.4cm^{-1}$ @810nm	
Intrinsic loss:	$0.02cm^{-1}$ @1064nm	
Gain bandwidth:	0.96nm @1064nm	
Polarized laser emission:	polarization; parallel to optic axis(c-axis)	
Diode pumped optical to optical efficiency:	>60%	

Laser Properties of Nd:YVO4

Laser crystal	Doping (atm%)	$s(x10^{-19}cm^2)$	a (cm^{-1})	t (ms)	l_a (mm)	P_{th}(mW)	h_s(%)
Nd:YVO4(a-cut)	1.0	25	31.2	90	0.32	30	52
	2.0	25	72.4	50	0.14	78	48.6
Nd:YVO4(c-cut)	1.1	7	9.2	90		231	45.5
Nd:YAG	0.85	6	7.1	230	1.41	115	38.6

Neodymium Doped Gadolinium Orthovanadate (Nd:$GdVO_4$)

Advantages:

◇Larger stimulated emission cross section at 1064nm than Nd:YAG;
◇Higher absorption coefficient at 808nm than Nd:YAG;
◇Better thermal conductivity than Nd:YVO4;
◇Low lasing threshold and high slope efficiency;
◇High laser induced damage threshold;
◇Strongly-polarized laser output;

WITCORE 'S warranty:

◇ Standard size crystal for application; ◇Strict Quality Control;
◇1 - 3 Weeks Delivery ; ◇ Attractive Price and quantity discount;
◇ Mass Production to Support Industrial and Commercial Applications;

WITCORE's specifications of Nd:$GdVO_4$

Dimension tolerance:	±0.1mm
Flatness:	λ/8 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec
Perpendicularity:	better than 15 arc min
Angle tolerance:	< +/0.5°
AR coating:	AR coating, HR Coating
residual reflectivity:	R0.2%@1064, HR:R>99.8%@1064,R<5%@808nm,
Clear aperture	>90% central area
Transmitting wavefront distortion:	less than ⎣/8 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Doped	Coating
NGV030306	3*3*6mm	0.5 at %	AR/AR
NGV040408	4*4*8mm	0.5 at %	AR/AR
NGV040410	4*4*10mm	0.5 at %	AR/AR
NGV050501	5*5*1mm	1.0at%	AR,HR
NGV101001	10*10*1mm	1.0at%	AR,HR
Other Nd:GdYVO4 crystals components offered as custom required.			

Basic Properties:

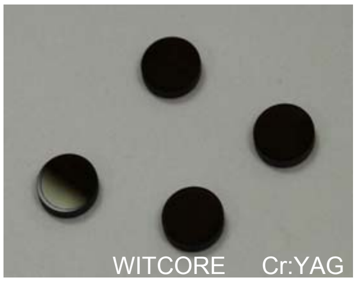
Crystal structure	Zircon Tetragonal, space group D4h-I4/amd
Nd Dopant level (atomic)	0.2%, 0.5%, 1.0%

Lattice parameter	a=0.721nm, b=0.635nm
Melting temperature	1780℃
Density	5.48g/ cm^3
Mohs hardness:	4.6-5
Lasing Transition	$^4F_{3/2}$ $^4I_{11/2}$
Lasing wavelength	1063nm, 1340nm
Stimulated emission Cross Section (E// C, at 1064nm)	$7.6x10^{-19}cm^2$
Absorption Cross Section (E // C, at 808nm)	$4.9x10^{-1}$ cm^2
Absorption Coefficient (E //C, at 808nm)	$74cm^{-1}$
Index of Refractivity (at 1064nm)	n_o=1.972, n_e =2.192
Thermal Expansion Coefficient (300K)	〈 a=1.5x10-6/K , 〈 c=7.3x10-6/K
Thermal Conductivity	11.7W/m/K
Line width:	3 nm

Information Regarding Neodymium Laser Host Crystals:

at 1% Nd doping:	Nd:GdVO4	Nd:YVO4	Nd:YAG
Laser wavelengths	1062.9 nm 1034.0 nm	1064.3nm 1342.0 nm	1064.2 nm 1338.2 nm
Emission bandwidth (line width at 1064 nm)	3nm	0.8 nm	0.45 nm
Effective laser cross section(emission cross section at 1064 nm)	$7.6 x 10^{-19}cm^2$	$15.6 x 10^{-19}cm^2$	$2.8 x 10^{-19}cm^2$
Polarization	Parallelto c-axis	Parallel to c-axis	Unpolarized
Fluorescence lifetime (microseconds)	~ 120 µs 150µs at 0.5at%	~ 100 µs	230 µs
Pump wavelength	808.4 nm	808.5 nm	807.5 nm
Peak pump absorption	~ 57 cm^{-1}	~ 41 cm^{-1}	-----
Thermal conductivity, W/m/K	11.7	5.1	14

Chromium Doped Yttrium Aluminum Garnet (Cr:YAG)



Cr: Y3Al5O12 crystal is one of the most promising passive Q-switching materials for passively Q-Switching Nd or Yb lasers at wavelength from 0.8 to 1.2um.The preliminary experiments of Cr:YAG showed that the pulse width of passively Q-switched lasers could be as short as 9 ns for diode pumped Nd:YAG lasers and repetition rate as high as 10kHz for diode pumped Nd:YVO4 lasers. Furthermore, an efficient green output @ 532 nm, and UV output @ 355 nm and 266 nm were generated, after a subsequent intracavity SHG in KTP or LBO, THG and 4HG in LBO and BBO for diode pumped
and passive Q-switched Nd:YAG and Nd:YVO4 lasers.

Advantages:

- ◇ High chemical stability and reliability.
- ◇ Long life time and good thermal conductivity
- ◇high damage threshold (>500MW/cm2)
- ◇ Easy to be operation
- ◇ As high power, solid state and compact passive Q-Switch

Main Specifications

Size	2x2 ~ 14x14mm
Length	0.1 ~ 12mm
Initial transmission	10% ~ 90%
Dimension tolerance:	(W ± 0.1mm) x (H ± 0.1mm) x (L + 0.2mm/-0.1mm)
Flatness:	λ/8 @ 633nm
Scratch/Dig code:	10/5 Scratch/dig per MIL-O-13830A
Parallelism:	better than 20 arc seconds
Perpendicularity:	5 arc minutes
AR-Coating:	R <0.2% @ 1064nm
NOTE: Inquiry or order the Cr4+ crystals, please write the specification listed above in particular the size, initial transmission and coatings.	

Basic Properties:

Crystal Structure	Cubic
Density	4.56g/cm^2
Melting Point	1970℃
Mohs Hardness	8.5
Dopant	0.5~3% Cr
Recovery time	8.5 μs
Thermal Conductivity	12.13W/m/K
Loss Coefficient	0.003cm^{-1}
Refractive index	1.82@1064nm
Base state absorption cross section	σ=4.3x10^{-18}/cm^2
Emission state absorption cross section	σs2=8.2 x10^{-19}/cm^2
Fluorescence lifetime	3.4μs

Yttrium Orthovanadate (YVO_4) Crystal

The yttrium orthovanadate (YVO_4), a kind of crystal preferably grown with Czochralski method has good mechanical and physical properties. It is ideal for optical polarizing components because of its wide transparency range and large birefringence. It is an excellent synthetic substitute for Calcite ($CaCO_3$) and Rutile (TiO_2) crystals in many applications including fiber optic isolators and circulators, beam displacers, Glan polarizers and other polarizing.

Applications:

◇Fiber-Optic Isolators, YVO_4 Beam Displacer, Circulators, Glan Polarizer, etc

WITCORE 's specifications of YVO_4 :

Dimension tolerance:	±0.05mm
Flatness:	λ/4 @633nm
Surface quality: Scratch/Dig	10/5
Parallelism:	better than 20 arc sec
Perpendicularity:	better than 15 arc min
Orientation tolerance:	△ <+/- 0.5°
AR coating:	AR: R<0.2%@633nm, 1310nm, 1550nm
Clear aperture:	>90% central area
Transmitting wavefront distortion:	ess than /4 @ 633nm
Quality Warranty Period:	one year under proper use

Standard products:

Part No	Sizes	Specification	Coating
YBW1101	1.25*1.25*0.5mm	phi=22.5° with 13° or 15° wedge	AR/AR
YBD2201	2*2*7mm	The=45,phi=0	AR/AR
YBD2202	2.6*2.6*7mm	The=45,phi=0	AR/AR
YBD3301	3.5*6*18mm	The=45,phi=0	AR/AR
Other YVO4 crystals components offered as custom required			

Basic Properties:

Transparency Range	high transmittance from 0.4 to 5mm
Crystal Symmetry	Zircon Tetragonal, space group D_{4h}
Lattice Parameters	a=b=0.712nm; c=0.629 nm
Density:	4.22 g/cm3
Hygroscopic Susceptibility:	Non-hygroscopic
Thermal Expansion Coefficient	aa = 4.43 x 10-6/K; ac = 11.37 x 10-6/K

Thermal Conductivity Coefficient	// C: 5.23 W/m/K; ^ C: 5.10 W/m/K		
Crystal Class:	Positive uniaxial with no=na=nb, ne=nc		
Thermal Optical Coefficient:	dna/dT = 8.5x10-6/K; dnc/dT = 3.0x10-6/K		
Sellmeier Equation (λ in ∝ m):	$n\ 2=3.77834 + 0.069736/(\lambda^2 - 0.04724) - 0.0108133\lambda^2$ $n\ 2=4.59905 + 0.110534/(\lambda^2 - 0.04813) - 0.0122676\lambda^2$		
Refractive Indices:	0.6341 mm	1.30 mm	1.55 mm
n_o	1. 9929	1.950	1.9447
n_e	2.2154	2.1554	2.1486
Birefringence ($Dn = n_e - n_o$),	0.2225	0.2054	0.2039
Walk-off Angle at 45° (r)	6.04° @633nm	5.72° @1310nm	5.69° @1550nm

Comparison with other Birefringent crystals:

		YVO_4	TiO_2	$CaCO_3$	$LiNbO_3$
Thermal Expansion (/C°)	c-axis	$11.4x10^{-6}$	$9.2x10^{-6}$	$26.3x10^{-6}$	$16.7x10^{-6}$
	a-axis	$4.4x10^{-6}$	$7.1x10^{-6}$	$5.4x10^{-6}$	$2x10^{-6}$
Refractive Index	n	1.9447@1550nm	2.454@1530nm	1.6346@1497nm	2.2151@1440nm
	n	2.1486@1550nm	2.710@1530nm	1.4774@1497nm	2.1413@1440nm
Birefringence (n -n)		0.2039@1550nm	0.256@1530nm	-0.1572@1497nm	-0.0738@440nm)
Mohs Hardness		5			
Transparency range		0.4-5m m			

Diffusion Bonding Composite Crystal (DBC Crystal)

WITCORE recently announced Diffusion Bonding Composite Crystal (DBC Crystal). DBC crystal consists of one or two un-doped and one laser crystal by diffusion bonding technology.

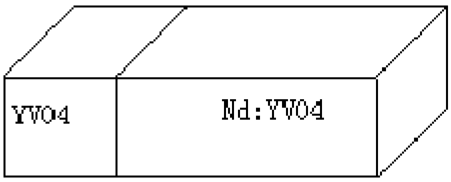
FEATURES:

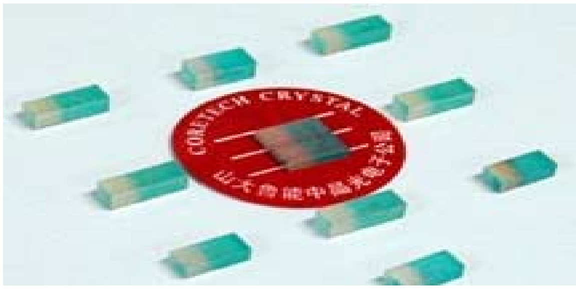
◇Low thermal effect

◇High laser damage threshold

◇High efficiency and good beam quality

◇Excellent for High-Average-Power DPSS Lasers.





WITCORE standard DBC crystal products:

Material	Doping Level	Aperture(mm)	Length (mm)
YVO_4+Nd:YVO_4+YVO_4	0.1-3%	3x3-10x10	11-20
YVO_4+Nd:YVO_4+YVO_4	0.1-3%	3x3-10x10	12-20
YAG+Nd:YAG	0.5-1.1%	Dia.2-10	1-50
YAG+Nd:YAG+YAG	0.5-1.1%	Dia.3-10	5-50
Other DBC crystals offered as custom required.			

Standard Specification:

Nd:YVO4 Doping	0.1-3%
Nd:YAG Doping	0.5-1.1%
Wavefront Distortion	$<\lambda/8$ at 633 nm
Orientation	< 0.5deg.
Dimensional Tolerance	< 0.1mm
Surface quality	10/5 Scratch/Dig per MIL-O-13830B
Flatness	$\lambda/10$ at 633 nm

Clear Aperture	> Central 95%
Parallelism	< 20 arc sec.
Coating:	AR or HR coating

Other Laser Crystals

We also would like to provide the following laser crystals:

- **Yb:YAG Crystal**
- **Nd:Ce:YAG Crystal**
- **Nd:GdYVO$_4$ Crystal**
- **Nd:YLF Crystal**
- **Ti:Sapphire Crystal**

Please do not hesitate to contact us, if you have any requirement for laser crystals.

Purchasing Information

Purchase order should have the following information:

◇Processing specification
◇Coating description
◇Quantity
◇Price
◇PO number

Customer's information which includes:

◇Complete company name
◇Contact person and phone/ fax number/ e-mail
◇Shipping address
◇Billing address

Price:

◇Prices will be quoted usually in USD/ EUR with validity of three months.
◇Products are normally shipped FOB from Jinan city, Shandong Province, P.R.China.
◇Shipping and handling charges and any bank transaction fees will be specified in concrete quotation.

Payment

◇Payments are usually in US dollars and should be sent by T/T, net 30 days.

Guaranty

◇All products are guaranteed to be free of defection in material from the date of purchase.
◇Repair or replace will be at no charge if we are notified of the defects within 15 days of receiving of the goods.
◇This warranty does not apply to failure of the product due to abuse, misuse, or accident.

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