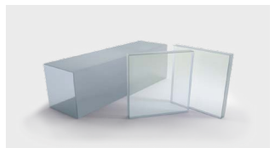
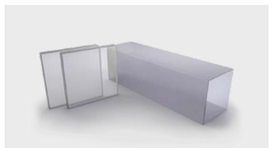
Nonlinear crystals

Nonlinear optical crystals are used in many different nonlinear parametric applications. To mention a few: second harmonic generation, difference frequency generation, optical parametric amplification and others. A proper crystal has to be chosen in order to use it for a particular application. It should have transparency in the required spectral range, adequate birefringence for phase-matching, a high nonlinear coefficient, high optical damage threshold, and other properties. Contact 4Lasers team for assistance and custom solutions.

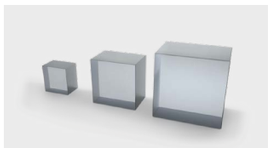
4Lasers develops and supplies different nonlinear crystals for fundamental, applied research and industrial applications. Available crystal growth techniques: Stepanov, Kyropoulos, Czochralski (CZ), temperature gradient technique (TGT), flux method.



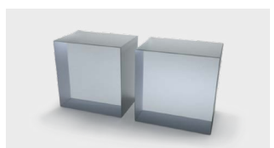
BBO crystals



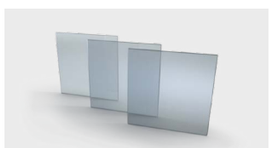
LBO crystals



KTP crystals

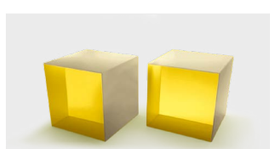


KDP, DKDP crystals



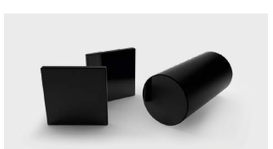
Lithium niobate crystals

$AgGaSe_2$ crystals



$AgGaS_2$ crystals

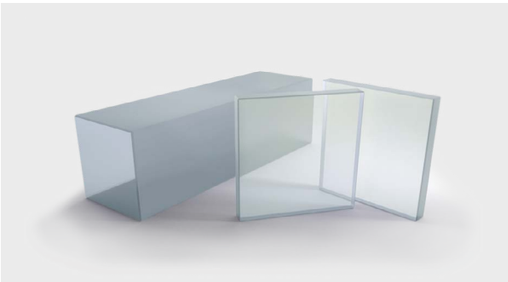
$ZnGeP_2$ crystals



CdSe crystals

GaSe crystals

BBO crystals



BBO crystal transparency ranges from 188 nm to 5,2 µm, which includes reasonable transparency from 3 µm - 5,2 µm for few tens µm thick crystals, while their phase-matchable range spans almost over the entire transparency range. Combined with other magnificent properties of BBO, it is favorable for numerous nonlinear parametric applications, e.g. harmonic generation of pulsed Yb-doped crystal based lasers and frequency doubling, tripling of Ti:Sapphire lasers, widely tunable type I and II OPO. It is worth to mention that BBO crystals have the highest nonlinearity in the UV range out of all common nonlinear crystals.

Main features

- Broad transparency ranges from 188 nm to 5,2 µm (reasonable transparency @3 µm - 5,2 µm for few tens µm thick crystals)
- Broad phase-matchable range for various second order nonlinear interactions over almost the entire transparency range
- Wide thermal acceptance bandwidth
- Highest nonlinearity of all UV nonlinear crystals
- High laser induced damage threshold
- Ultrathin crystals available for few optical cycle laser pulses
- Custom size, orientation and coatings are available upon request

Application examples

- Harmonic generation (up to fifth) of pulsed Nd-doped crystal based lasers
- Frequency doubling, tripling of pulsed Ti:Sapphire, Yb-doped, dye lasers
- Widely tunable type I and II OPO
- Characterization of ultrashort laser pulses by FROG, XFROG, SPIDER, dispersion scan, chirp scan methods

Standard specifications

BBO CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>90%
Face dimensions tolerance	+0,0/-0,1 mm
Parallelism error	<20 arcsec
Perpendicularity error	<5 arcmin
Protective chamfers	<0,1 mm at 45°
Surface quality	10-5 S-D
Wavefront distortion	<λ/8@632,8 nm
Coatings	Low dispersion protective coatings or antireflective coatings on both sides
Laser induced damage threshold	>500 MW/cm²@1064 nm, 10 ns
UVFS support	Crystals with <0,1 mm thickness are optically contacted to 0,5-1 mm UVFS support
Mount	Mounted in ø25,4 mm black or natural aluminum mount

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	β-BaB_2O_4
Crystal structure	Rhombohedral, 3m
Lattice parameters	a=12,532 Å, c=12,717 Å
Optical symmetry	Negative uniaxial ($n_o > n_e$)
Density	3,85 g/cm^3
Mohs hardness	4-4,5
Transparency range	188 nm – 5,2 µm, reasonable from 3 µm to 5,2 µm for thin crystals (few tens of µm)
Sellmeier equations @188 nm - 5,2 µm range (λ in µm)	$n_o^2 = 1 + 0{,}90291\ \lambda^2/(\lambda^2 - 0{,}003926) + 0{,}83155\ \lambda^2/(\lambda^2 - 0{,}018786) + 0{,}76536\ \lambda^2/(\lambda^2 - 60{,}01)$; $n_e^2 = 1 + 1{,}151075\ \lambda^2/(\lambda^2 - 0{,}007142) + 0{,}21803\ \lambda^2/(\lambda^2 - 0{,}02259) + 0{,}656\ \lambda^2/(\lambda^2 - 263)$
Refractive indices	n_o = 1,6551, n_e = 1,5426 @1064 nm

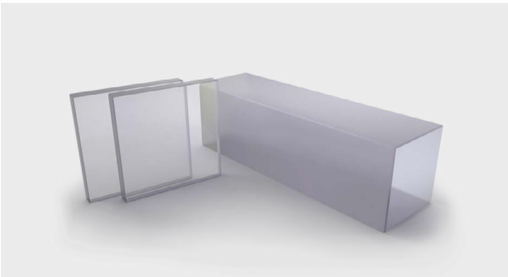
Guidance

4Lasers provide guidance and theoretical calculations for particular BBO applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
6 x 6 mm	0,1 mm	50°	90°	P/P@515/257 nm	SHG@515 nm, 50 fs, type I	15808	500 €
	0,15 mm	50°	90°	P/P@515/257 nm	SHG@515 nm, 100 fs, type I	15809	480 €
	0,3 mm	50°	90°	P/P@515/257 nm	SHG@515 nm, 200 fs, type I	15810	450 €
	0,05 mm	29,2°	90°	P/P@400-800 nm	SHG@800 nm, 10 fs, type I	15811	620 €
	0,1 mm	29,2°	90°	P/P@400-800 nm	SHG@800 nm, 20 fs, type I	6399	450€
	0,2 mm	29,2°	90°	P/P@400-800 nm	SHG@800 nm, 50 fs, type I	15833	430 €
	0,5 mm	29,2°	90°	P/P@400-800 nm	SHG@800 nm, 100 fs, type I	6398	390 €
	1 mm	29,2°	90°	P/P@400-800 nm	SHG@800 nm, 200 fs, type I	6400	350 €
	0,5 mm	23,4°	90°	AR/AR@515+1030 nm	SHG@1030 nm, 50 fs, type I	9447	440 €
	1 mm	23,4°	90°	AR/AR@515+1030 nm	SHG@1030 nm, 100 fs, type I	9448	380 €
	1,5 mm	23,4°	90°	AR/AR@515+1030 nm	SHG@1030 nm, 150 fs, type I	9449	410 €
	2 mm	23,4°	90°	AR/AR@515+1030 nm	SHG@1030 nm, 200 fs, type I	10733	410 €
	0,01 mm	44,3°	90°	P/P@400-800 nm	THG@800 nm, 10 fs, type I	15834	800 €
	0,02 mm	44,3°	90°	P/P@400-800 nm	THG@800 nm, 20 fs, type I	15835	780 €
	0,05 mm	44,3°	90°	P/P@400-800 nm	THG@800 nm, 50 fs, type I	15836	700 €
	0,1 mm	44,3°	90°	P/P@400-800/266 nm	THG@800 nm, 100 fs, type I	9044	450 €
	0,2 mm	44,3°	90°	P/P@400-800/266 nm	THG@800 nm, 200 fs, type I	15837	450 €
	0,15 mm	32,5°	90°	AR/AR@515+1030/343 nm	THG@1030 nm, 50 fs, type I	9450	630 €
	0,25 mm	32,5°	90°	AR/AR@515+1030/343 nm	THG@1030 nm, 100 fs, type I	9451	580 €
	0,55 mm	32,5°	90°	AR/AR@515+1030/343 nm	THG@1030 nm, 200 fs, type I	9452	470 €

LBO crystals



Lithium Triborate (LiB_3O_5, LBO) crystals feature a broad transparency range, wide acceptance angle, small walk-off angle and the highest damage threshold among common nonlinear crystals. Most common applications include high-power near-infrared wavelength second harmonic generation, sum frequency generation to produce visible, ultraviolet laser light and visible, near-infrared widely tuned optical parametric oscillators. 4Lasers are capable of providing uncoated super-polished LBO crystals desired, e.g. for high-power UV generation via sum-frequency generation of 1064 nm and 532 nm.

Main features

- Broad transparency range from 155 nm to 3200 nm
- Absence of photochromic damage (gray-tracking)
- Highest damage threshold among common nonlinear crystals
- Small walk-off angle at room temperature, no walk-off at NCPM regime
- Wide acceptance angle
- Temperature tunable type I and II non-critical phase-matching
- Super-polished and custom crystals available upon request

Application examples

- Sum-frequency generation of 532 nm and 1064 nm to produce 355 nm UV radiation
- Widely tunable OPOs in NIR range pumped by second harmonic of Nd-doped lasers
- Efficient second harmonic generation at 1064 nm without walk-off effect (NCPM, t = 149 °C)

Standard specifications

LBO CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>90%
Face dimensions tolerance	+0,0/-0,1 mm
Length tolerance	±0,1 mm
Parallelism error	<20 arcsec
Perpendicularity error	<10 arcmin
Protective chamfers	<0,1 mm at 45°
Surface quality	10-5 S-D
Wavefront distortion	<λ/4@632,8 nm
Coatings	AR coatings on both sides
Laser induced damage threshold	>1 GW/cm²@1064 nm, 10 ns
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	LiB_3O_5
Crystal structure	Orthorhombic, mm^2
Lattice parameters	a = 8,46 Å, b = 7,38 Å , c = 12,717 Å
Optical symmetry	Negative biaxial ($2V_z$ = 109,2° @0,5321 µm)
Density	2,474 g/cm³
Mohs hardness	6-7
Transparency range	155 nm - 3,2 µm @~0~ transmittance level
Sellmeier equations @T = 293 K (λ in µm)	$n_x^2 = 2{,}4542 + 0{,}01125/(\lambda^2 - 0{,}01135) - 0{,}01388\,\lambda^2$; $n_y^2 = 2{,}5390 + 0{,}01277/(\lambda^2 - 0{,}01189) - 0{,}01849\,\lambda^2 + 4{,}3025\times10^{-5}\lambda^4 - 2{,}9131\times10^{-5}\lambda^6$; $n_z^2 = 2{,}5865 + 0{,}0131/(\lambda^2 - 0{,}01223) - 0{,}01862\,\lambda^2 + 4{,}5778\times10^{-5}\lambda^4 - 3{,}2526\times10^{-5}\lambda^6$
Refractive indices	n_x = 1,5656; n_y = 1,5905; n_z = 1,6055 @1064 nm

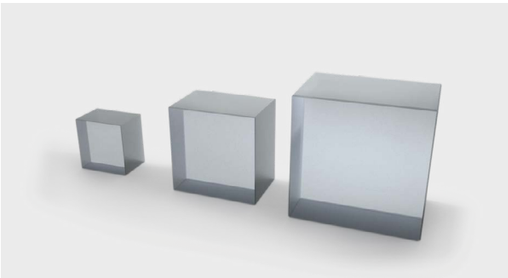
Guidance

4Lasers provides guidance and theoretical calculations for particular LBO applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
3 x 3 mm	10 mm	90°	11,6°	AR/AR@532+1064 nm	SHG@1064 nm, type I	7203	210 €
	10 mm	42,2°	90°	AR/AR@532+1064/355 nm	THG@1064 nm, type II	7199	230 €
	10 mm	90°	0°	AR/AR@532+1064 nm	NCPM SHG@1064 nm, T = 149 °C	7209	210 €
	20 mm	90°	11,6°	AR/AR@532+1064 nm	SHG@1064 nm, type I	7202	360 €
	20 mm	42,2°	90°	AR/AR@532+1064/355 nm	THG@1064 nm, type II	9457	380 €
	20 mm	90°	0°	AR/AR@532+1064 nm	NCPM SHG@1064 nm, T = 149 °C	7210	360 €
5 x 5 mm	10 mm	90°	11,6°	AR/AR@532+1064 nm	SHG@1064 nm, type I	7207	580 €
	10 mm	42,2°	90°	AR/AR@532+1064/355 nm	THG@1064 nm, type II	7204	610 €
	20 mm	90°	11,6°	AR/AR@532+1064 nm	SHG@1064 nm, type I	7208	850 €
	20 mm	42,2°	90°	AR/AR@532+1064/355 nm	THG@1064 nm, type II	9459	900 €
6 x 6 mm	1 mm	90°	13,8°	AR/AR@515+1030 nm	SHG@1030 nm, type I	9458	430 €
	2 mm	90°	13,8°	AR/AR@515+1030 nm	SHG@1030 nm, type I	9460	400 €
	3 mm	90°	13,8°	AR/AR@515+1030 nm	SHG@1030 nm, type I	9461	450 €
	4 mm	90°	13,8°	AR/AR@515+1030 nm	SHG@1030 nm, type I	9462	430 €

KTP crystals



Potassium titanyl phosphate ($KTiOPO_4$, KTP) crystals are advantageous due to their high nonlinearity, great mechanical stability, high optical quality and transparency range of 350 nm - 4,5 µm. These features determine the wide application of KTP crystals as a nonlinear medium. It is an excellent solution for frequency doubling applications of Nd-doped lasers, especially for low and medium power applications, both intra- and extra-cavity design. Besides, these crystals can be used as a nonlinear OPO medium for IR generation up to 4 µm and used as a pump source for mid-IR nonlinear crystal based optical parametric oscillators, such as ZGP OPO. KTP is susceptible to photochromic damage (grey-tracking), which causes deterioration of nonlinear conversion efficiency. 4Lasers provide high grey track resistance (HGTR) KTP crystals as a solution, which significantly improves the grey-track resistance and overall performance. HGTR KTP crystals extend the use of KTP as a nonlinear medium to high-power applications.

Main features

- High nonlinearity
- Nonhygroscopic crystal
- Great mechanical stability
- Wide transparency range from 350 nm to 4,5 µm
- Broad angular and thermal acceptance
- Broad type I and II non-critical phase-matching range

Application examples

- Low and medium power frequency doubling of Nd-doped lasers
- KTP OPO and ZGP OPO tandem for mid-infrared generation

Standard specifications

KTP CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>90%
Face dimensions tolerance	+0,0/-0,1 mm
Length tolerance	±0,1 mm
Parallelism error	<20 arcsec
Perpendicularity error	<5 arcmin
Protective chamfers	<0,1 mm at 45°
Surface quality	10-5 S-D
Wavefront distortion	<λ/8@632,8 nm
Coatings	AR(R<0,25%)532+1064 nm on both faces
Laser induced damage threshold	>500 MW/cm²@1064 nm, 10 ns
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	$KTiOPO_4$
Crystal structure	Orthorhombic, mm^2
Lattice parameters	a = 12,814 Å, b = 6,404 Å, c = 10,616 Å
Optical symmetry	Positive biaxial ($2V_z$ = 37,4° @0,5461 µm)
Density	2,945 g/cm^3
Mohs hardness	5
Transparency range	350 nm - 4,5 µm @"0" transmittance level
Sellmeier equations (λ in µm)	$n_x^2 = 3{,}0067 + 0{,}0395/(\lambda^2 - 0{,}04251) - 0{,}01247\,\lambda^2$; $n_y^2 = 3{,}0319 + 0{,}04152/(\lambda^2 - 0{,}04586) - 0{,}01337\,\lambda^2$; $n_z^2 = 3{,}3134 + 0{,}05694/(\lambda^2 - 0{,}05941) - 0{,}016713\,\lambda^2$
Refractive indices	n_x = 1,7404; n_y = 1,7479; n_z = 1,8296 @1064 nm

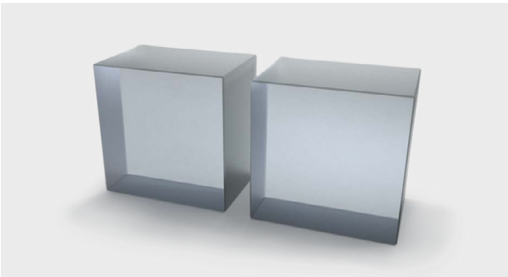
Guidance

4Lasers provide guidance and theoretical calculations for particular KTP applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATING	APPLICATION	SKU	PRICE
3 x 3 mm	5 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7184	75 €
	10 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7188	105 €
5 x 5 mm	5 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7189	180 €
	10 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7193	290 €
7 x 7 mm	5 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7194	350 €
	10 mm	90°	23,5°	AR/AR@532+1064 nm	SHG@1064 nm, type II	7198	495 €

KDP, DKDP crystals



Potassium dihydrogen phosphate (KH_2PO_4, KDP) and potassium dideuterium phosphate (KD_2PO_4, DKDP) crystals are one of the oldest used nonlinear materials. DKDP and KDP are known as analogs, though their properties differ due to DKDP deuteration. They both exhibit excellent ultraviolet transmission and high damage threshold. The nonlinearity of these crystals is relatively low, these crystals can be grown in large size. They found their application as nonlinear frequency doublers, triplers and quandruplers of Nd-doped lasers and as Q-switch devices for Ti:Sapphire, Alexandrite, Nd-doped lasers. Main drawback is that these crystals are highly hygroscopic, therefore sealed housing and dry operating conditions have to be ensured.

Main features

- Excellent ultraviolet radiation transmission
- High laser induced damage threshold
- Custom crystals available upon request

Application exalmples

- Frequency doublers, triplers and quadruplers for Nd-doped lasers
- Q-switches for Ti:Sapphire, Alexandrite, Nd-doped lasers

Standard specifications

KDP AND DKDP CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>90%
Face dimensions tolerance	+0,0/-0,1 mm
Length tolerance	±0,1 mm
Parallelism error	<20 arcsec
Perpendicularity error	<5 arcmin
Protective chamfers	<0,1 mm at 45°
Surface quality	20-10 S-D
Surface flatness	<λ/4@632,8 nm
Coatings	AR coatings on both sides
Laser induced damage threshold	>10 J/cm²@1064 nm, 10 ns for KDP crystals >5 J/cm²@1064 nm, 10 ns for DKDP
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES		
Chemical formula	KH_2PO_4 (KDP)	KD_2PO_4 (DKDP)
Crystal structure	Tetragonal, 42m	Tetragonal, 42m
Lattice parameters	a = 7,448 Å, c = 6,977 Å	a = 7,4697 Å, c = 6,966 Å
Optical symmetry	Negative uniaxial ($n_o > n_e$)	Negative uniaxial ($n_o > n_e$)
Density	2,332 g/cm³	2,355 g/cm³
Mohs hardness	2,5	2,5
Transparency range	180 nm - 1,5 μm	200 nm - 2 μm
Refractive indices	n_o = 1,4938, n_e = 1,4599 @1,06 μm	n_o = 1,4931; n_e = 1,4582 @1,06 μm
KDP Sellmeier equations @T = 293 k (λ in μm)	$n_o^2 = 2{,}259276 + 13{,}00522\ \lambda^2/(\lambda^2 - 400) + 0{,}01008956/(\lambda^2 - (77{,}26408)^{-1})$; $n_e^2 = 2{,}132668 + 3{,}2279924\ \lambda^2/(\lambda^2 - 400) + 0{,}008637494/(\lambda^2 - (81{,}42631)^2)$	
DKDP Sellmeier equations @T = 293 K (λ in μm)	$n_o^2 = 2{,}240921 + 2{,}246956\ \lambda^2/(\lambda^2 - (11{,}26591)^2) + 0{,}009676/(\lambda^2 - (0{,}124981)^2)$; $n_e^2 = 2{,}126019 + 0{,}784404\ \lambda^2/(\lambda^2 - (11{,}10871)^2) + 0{,}008578/(\lambda^2 - (0{,}109505)^2)$	

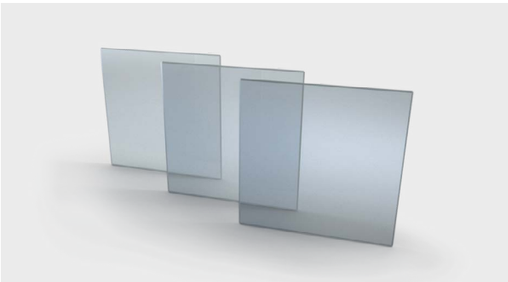
Guidance

4Lasers provide guidance and theoretical calculations for particular KDP and DKDP applications. Contact us and we will help you to configure your crystal.

Standard products

MATERIAL	FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
KDP	12 x 12 mm	5 mm	76,5°	45°	AR/AR@532/266 nm	SHG@532 nm, type I	9421	360 €
	15 x 15 mm	7 mm	76,5°	45°	AR/AR@532/266 nm	SHG@532 nm, type I	9422	415 €
DKDP	12 x 12 mm	20 mm	53,5°	0°	AR/AR@1064/532+1064 nm	SHG@1064 nm, type II	9426	410 €
	12 x 12 mm	20 mm	59,3°	0°	AR/AR@1064/532+1064 nm	THG@1064 nm, type II	9425	410 €
	15 x 15 mm	13 mm	36,5°	45°	AR/AR@532+1064 nm	SHG@1064 nm, type I	9423	420 €
	15 x 15 mm	13 mm	53,5°	0°	AR/AR@532+1064 nm	SHG@1064 nm, type II	9424	420 €
	15 x 15 mm	20 mm	53,5°	0°	AR/AR@1064/532+1064 nm	SHG@1064 nm, type II	9427	515 €
	15 x 15 mm	20 mm	59,3°	0°	AR/AR@532+1064/355 nm	THG@1064 nm, type II	9428	515 €

Lithium niobate crystals



Lithium niobate ($LiNbO_3$, LN) is a multi-purpose material in photonics and optoelectronics fields. It features a wide transparency range from 420 nm to 5,2 µm, excellent nonlinear, electro-optic, and piezoelectric properties. Most common applications include infrared range optical modulation and Q-switching, nonlinear frequency conversion of >1 µm wavelengths. Their electrical and optical properties can be adjusted using magnesium or zirconium dopants.

Main features

- Broad transparency region from 420 nm to 5200 nm
- High nonlinear, electro-optic and acousto-optic coefficients
- Nonhygroscopic, mechanically, and chemically stable

Application examples

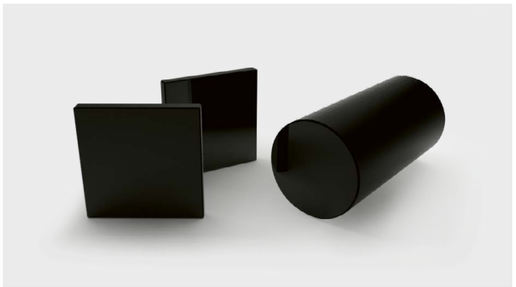
- Electro-optic modulation and Q-switching
- Optical parametric oscillators (OPO) pumped at 1064 nm
- Quasi-phase-matched devices with periodically poled lithium niobate (PPLN)

4Lasers does not provide standard product list. Please contact us for solutions and pricing.

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	$LiNbO_3$
Crystal structure	Trigonal, 3m
Optical symmetry	Negative uniaxial (n_o>n_e)
Density	4,64 g/cm^3
Mohs hardness	5
Transparency range	420 nm - 5,2 µm
Sellmeier equations (λ in µm)	$n_o^2 = 4{,}9048 + 0{,}11768/(\lambda^2 - 0{,}04750) - 0{,}027169\ \lambda^2$; $n_e^2 = 4{,}5820 + 0{,}099169/(\lambda^2 - 0{,}04443) - 0{,}021950\ \lambda^2$
Refractive indices	n_o = 2,220; n_e = 2,146 @1064 nm

CdSe crystals



Cadmium selenide (CdSe) crystals feature an infrared transmission up to 24 µm, reasonably large nonlinearity and small walk-off angle. CdSe crystals can be employed into difference frequency generation (DFG), optical parametric oscillation (OPO) schemes to generate infrared laser radiation above ZGP absorption edge (>12 µm). For instance, CdSe OPO can potentially be pumped by 2 µm Tm-doped, Ho-doped, Tm and Ho co-doped lasers and produce far infrared idler radiation. Besides nonlinear optic applications cadmium selenide crystal material can be used for IR optical elements: substrates, polarizers, waveplates, etc.

Main features

- Wide transparency range (0,7-24 µm)
- Reasonably large nonlinearity
- Small walk-off angle

Application examples

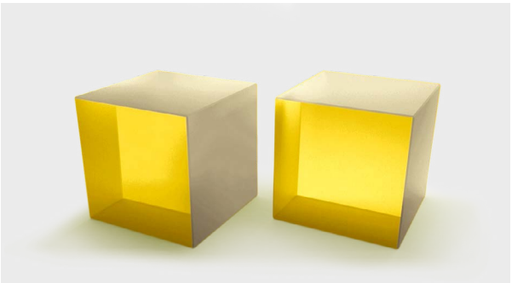
- Far infrared wavelength radiation generation by DFG, OPO schemes
- Material for infrared optical elements: substrates, polarizers, waveplates, etc.

4Lasers does not provide standard product list. Please contact us for solutions and pricing.

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	CdSe
Crystal structure	Hexagonal, 6mm
Lattice parameters	a = 4,2985 Å, c = 7,0150 Å
Optical symmetry	Positive uniaxial (n_e >n_o)
Density@288 K	5,81 g/cm^3
Mohs hardness	3,25
Transparency range	0,7-24 µm @"0" transmittance level)
Dispersion equations (@T = 293 K (λ in µm)	$n_o^2 = 4{,}2243 + 1{,}7680\ \lambda^2/(\lambda^2 - 0{,}2270) + 3{,}1200\ \lambda^2/(\lambda^2 - 3380)$; $n_e^2 = 4{,}2009 + 1{,}8875\ \lambda^2/(\lambda^2 - 0{,}2171) + 3{,}6461\ \lambda^2/(\lambda^2 - 3629)$
Refractive indices	n_o = 2,431, n_e = 2,452@10,0 µm
Thermal conductivity @T = 293 K	6,9 (||c) Wm^{-1}K^{-1}, 6,2 (⊥c) Wm-1K^{-1}
Laser induced damage threshold	60 MW/cm^2@10,6 µm, 200 ns

$AgGaS_2$ crystals



Silver Thiogallate ($AgGaS_2$, AGS) has been demonstrated as an efficient crystal for nonlinear parametric interactions in the infrared spectral range. Its transparency region ranges from 0,53 to 12 µm. AGS based optical parametric oscillators feature continuously tunable radiation over a wide range of wavelengths in the infrared spectral range. High transparency in the short wavelength range beginning at 550 nm is used in OPOs pumped by Nd:YAG laser.

Using 2050 nm pump laser, an optimally designed $AgGaS_2$ OPO is tunable from about 2.5 to 12.0 µm. The output range can be extended by the sum or difference frequency mixing (SFM/DFM). This crystal features a high non-linear coefficient, high damage threshold, and a wide transmission range. It also exhibits a low optical absorption and scattering, low wavefront distortion. $AgGaS_2$ has the highest figure of merit for non-linear interactions in the near and deep infrared.

Main features

- Unique non-linear properties across the transmission range from 0,5 to 12 µm
- Low optical absorption and scattering
- Transparency at short wavelengths

Application examples

- Frequency mixing in the middle IR region from 4,0 to 18,3 µm
- Second harmonic generation and up-conversion for CO_2 lasers
- Tunable OPO for solid-state lasers

Standard specifications

$AgGaS_2$ CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>80%
Face dimensions tolerance	+0,0/-0,2 mm
Parallelism error	<30 arcsec
Perpendicularity error	<10 arcmin
Protective chamfers	<0,2 mm at 45°
Surface quality	60-40 S-D
Coatings	BBAR/BBAR@1,2-2,6 µm/2,6-11 µm
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	$AgGaS_2$
Crystal structure	Tetragonal, 42m
Lattice parameters	a = 5,742 Å, c = 10,26 Å
Optical symmetry	Negative uniaxial ($n_o > n_e$, λ<0,497 µm $n_e > n_o$)
Density	4,58 g/cm^3
Mohs hardness	3-3,5
Transparency range	0,47 - 13 µm @"0" transmittance level
Sellmeier equations @T = 293 K (λ in µm)	$n_o^2 = 5{,}79419 + 0{,}23114/(\lambda^2 - 0{,}06882) - 2{,}4534 \times 10^{-3}\lambda^2 + 3{,}1814 \times 10^{-7}\lambda^4 - 9{,}7051 \times 10^{-9}\lambda^6$; $n_e^2 = 5{,}54120 + 0{,}22041/(\lambda^2 - 0{,}09824) - 2{,}5240 \times 10^{-3}\lambda^2 + 3{,}6214 \times 10^{-7}\lambda^4 - 8{,}3605 \times 10^{-9}\lambda^6$
Refractive indices	n_o = 2,3471; n_e = 2,2914 @ 10,6321 µm
Thermal conductivity	1,4 (∥c) Wm^{-1}K^{-1}, 1,5 (⊥c) Wm^{-1}K^{-1}

Guidance

4Lasers provides guidance and theoretical calculations for particular $AgGaS_2$ applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
5 x 5 mm	1 mm	39°	45°	BBAR/BBAR@1,2-2,6/2,6-11 µm	DFG@1,2-2,6 µm, type I	7356	Request
8 x 8 mm	1 mm	39°	45°	BBAR/BBAR@1,2-2,6/2,6-11 µm	DFG@1,2-2,6 µm, type I	7395	Request
6 x 6 mm	2 mm	50°	0°	BBAR/BBAR@1,2-2,6/2,6-11 µm	DFG@1,2-2,6 µm, type II	7396	Request
8 x 8 mm	2 mm	50°	0°	BBAR/BBAR@1,2-2,6/2,6-11 µm	DFG@1,2-2,6 µm, type II	7397	Request

$AgGaSe_2$ crystals

Silver gallium selenide ($AgGaSe_2$, AGSe) is an optically negative uniaxial crystal with a reasonable transmittance over roughly 0,7 µm - 18 µm region. AGSe crystals have proven to be used in nonlinear parametric downconversion (difference frequency generation, DGF) in the Mid-IR range by tandem with commercially available synchronously-pumped optical parametric oscillators (SPOPOs) in the femtosecond and picosecond regime [1]. AGSe crystal has one of the highest figure of merits (~70 pm^2/V^2) from commercially available mid-IR nonlinear crystals, which is six times larger than counterpart AGS. For some particular reasons AGSe is also a better choice over other mid-IR crystals. For example, even though GaSe has higher nonlinearity and comparable transparency region, AGSe has lower spatial walk-off and availability to be processed for particular application (growth and cut direction, dielectric thin-film coatings). ZGP has higher figure of merit, but its transparency region (~2-12 µm) is no match to AGSe.

Main features

- Excellent properties across the transmission range from 0,73 to 18 µm
- Low optical absorption and scattering
- High FOM (figure of merit) for non-linear interactions in NIR and MIR

Application examples

- Frequency mixing in the IR region from 4,0 to 18,3 µm
- Second harmonic generation and up-conversion for CO_2 lasers
- Tunable OPO for solid-state lasers with efficiency up to 10%

Standard specifications

$AgGaSe_2$ CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>80%
Face dimensions tolerance	+0,0/-0,2 mm
Parallelism error	<30 arcsec
Perpendicularity error	<10 arcmin
Protective chamfers	<0,2 mm at 45°
Surface quality	60-40 S-D
Coatings	BBAR/BBAR@1,7-2,7 µm/5-18 µm
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	$AgGaSe_2$
Crystal structure	Tetragonal, 42m
Lattice parameters	a = 5,9920 Å, c = 10,8803 Å
Optical symmetry	Negative uniaxial ($n_e > n_o$, λ<804 nm, $n_e > n_o$)
Density	5,7 g/cm^3
Mohs hardness	3-3,5
Transparency range	0,71 - 19 µm @"0" transmittance level
Sellmeier equations @T=293 K (λ in µm)	n_o^2=6,8507 + 0,4297/(λ^2 - 0,1584) - 0,00125 λ^2; n_e^2 = 6,6792 + 0,4598/(λ^2 - 0,2122) - 0,00126 λ^2
Refractive indices	n_o = 2,5917; n_e = 2,5585 @10,5 µm
Thermal conductivity @T = 293 K	1 (||c) $Wm^{-1}K^{-1}$, 1,1 (⊥c) $Wm^{-1}K^{-1}$
Laser induced damage threshold	>10 MW/cm^2@10,6 µm, 150 ns

Guidance

4Lasers provides guidance and theoretical calculations for particular $AgGaSe_2$ applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
5 x 5 mm	2 mm	52°	45°	BBAR@1,7-2,7 µm/BBAR@5-18 µm	Ultrashort pulse DFG@1,7-2,7 µm -> ~5-18 µm, type I	15806	Request
	5 mm	52°	45°	BBAR@1,7-2,7 µm/BBAR@5-18 µm	Ultrashort pulse DFG@1,7-2,7 µm -> ~5-18 µm, type I	15807	Request
	10 mm	52°	45°	BBAR@1,7-2,7 µm/BBAR@5-18 µm	Ultrashort pulse DFG@1,7-2,7 µm -> ~5-18 µm, type I	15805	Request

$ZnGeP_2$ crystals

Zinc-germanium diphosphide ($ZnGeP_2$, ZGP) crystals are considered as state-of-the-art mid-IR nonlinear crystals due to unique properties. They exhibit an excellent nonlinearity and thermal conductivity (36 W/mK@||c, 35 W/mK@⊥c) together with a relatively high laser induced damage threshold. ZGP crystal can be successfully implemented in high-power mid-IR harmonic generators, difference frequency generators and optical parametric oscillators due its broad useful transmission range (2-12 µm).

Main features

- Useful transmission range from 2 µm to 12 µm
- High nonlinearity
- Relatively high damage threshold
- Nominal absorption coefficient <0,04 cm^{-1} at ~2,1 µm for o-wave

Application examples

- Harmonic generation of CO_2 and CO laser fundamental wavelength
- Generation of continuously tunable radiation in MWIR, LWIR range by OPO and DFG techniques
- Generation of terahertz range frequencies

Standard specifications

$ZnGeP_2$ CRYSTALS	
Orientation accuracy	<30 arcmin
Clear aperture	>80%
Face dimensions tolerance	+0,0/-0,2 mm
Length tolerance	+1,0/-0,0 mm
Parallelism error	<30 arcsec
Perpendicularity error	<10 arcmin
Protective chamfers	<0,2 mm at 45°
Surface quality	60-40 S-D
Surface flatness	λ/4@632,8 nm
Coatings	Antireflective coatings @2,1 µm + 3,5-5 µm on both sides
Nominal absorption coefficient	<0,04 cm^{-1}@2,1 µm, o-wave
Mount	Unmounted

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	$ZnGeP_2$
Crystal structure	Tetragonal, 42m
Lattice parameters	a = 5,465 Å, c = 10,708 Å
Optical symmetry	Positive uniaxial ($n_e > n_o$)
Density	4,162 g/cm^3
Mohs hardness	5,5
Transparency range	0,74 - 12 µm @"0" transmittance level
Dispersion equations @1,5 - 10,59 µm range, T = 293 K (λ in µm)	n_o^2 = 11,6413 + 0,69363/(λ² - 0,21967) + 1586,06/(λ² - 832,75); n_e^2 = 12,1438 + 0,75255/(λ² - 0,21913) + 2061,68/(λ² - 951,07)
Refractive indices	n_o = 3,0738; n_e = 3,1137 @10,5 µm
Thermal conductivity @T = 293 K	36 (||c) $Wm^{-1}K^{-1}$, 35 (⊥c) $Wm\text{-}1K^{-1}$
Laser induced damage threshold	60 MW/cm^2@10,6 µm, 100 ns

Guidance

4Lasers provides guidance and theoretical calculations for particular $ZnGeP_2$ applications. Contact us and we will help you to configure your crystal.

Standard products

FACE DIMENSIONS	LENGTH	THETA	PHI	COATINGS	APPLICATION	SKU	PRICE
5 x 5 mm	10 mm	55,3°	0°	AR@2,1 µm + BBAR@3,5-5 µm	MWIR generation, type I, eeo interaction	15358	Request
	15 mm	55,3°	0°	AR@2,1 µm + BBAR@3,5-5 µm	MWIR generation, type I, eeo interaction	15359	Request
	20 mm	55,3°	0°	AR@2,1 µm + BBAR@3,5-5 µm	MWIR generation, type I, eeo interaction	15360	Request

GaSe crystals

4Lasers offer z-cut, cleaved surface and mounted gallium selenide (GaSe) crystals. Custom clear apertures and crystal thicknesses from tens of microns up to several millimeters are available upon request.

Due to fragile nature of GaSe it is not possible to apply antireflection coatings.

Main features

- Broad transparency range from 0,65 µm to 18 µm
- Large nonlinearity and birefringence
- Soft and cleaves along [001] plane
- Cannot be cut and polished at certain angles
- Comes uncoated and mounted for proper handling

Application examples

- Broadband mid-IR difference frequency generation
- Second harmonic (SH) of CO_2, CO, dye lasers
- Terahertz (THz) generation by optical rectification
- Terahertz detectors for terahertz time domain spectroscopy (THz-TDS)

Standard specifications

GaSe CRYSTALS	
Clear aperture	ø5 mm or custom
Surface quality	Cleaved surfaces
Coatings	Uncoated, unavailable
Mount	ø25,4 mm black anodized aluminum mount

Properties

PHYSICAL AND OPTICAL PROPERTIES	
Chemical formula	GaSe
Crystal structure	Hexagonal, -62m
Lattice parameters	A = 3,742 Å, c = 15,918 Å
Optical symmetry	Negative uniaxial (no>ne)
Density	5,03 g/cm^3
Mohs hardness	= 0
Transparency range	0,62-20 µm @ "0" transmittance level
Sellmeir equations	$n_o^2 = 7,443 + 0,4050/\lambda^2 + 0,0186/\lambda^4 + 0,0061/\lambda^6 + 3,1485\ \lambda^2/(\lambda^2 - 2194)$; $n_e^2 = 5,76 + 0,3879/\lambda^2 - 0,2288/\lambda^4 + 0,1223/\lambda^6 + 1,8550\ \lambda^2/(\lambda^2 - 1780)$
Refractive indices	$n_o = 2,8158$; $n_e = 2,4392$ @10,6 µm

Guidance

4Lasers provides guidance and theoretical calculations for particular GaSe applications. Contact us and we will help you to configure your crystal.

Standard products

CLEAR APERTURE	LENGTH	ORIENTATION	COATINGS	SKU	PRICE
ø5 mm	0,5 mm	z-cut	Uncoated	13185	1000 €
	1 mm	z-cut	Uncoated	11982	1125 €
	2 mm	z-cut	Uncoated	13183	1250 €