

3. Nonlinear Optics

3.1. Nonlinear Crystals

3.1.1. BBO Nonlinear Crystals



Broad phase-matchable SHG range from 409.6 nm to 3500 nm
Wide transmission region from 190 nm to 3500 nm
Large effective second-harmonic-generation (SHG) coefficient
High damage threshold of 10 GW/cm² for 100 ps pulse-width at 1064 nm
Good mechanical and physical properties

BBO is a non-linear optical crystal that combines a number of unique features.

These features of nonlinear BBO crystal include wide transparency and phase matching ranges, large non-linear coefficient, high damage threshold and excellent optical homogeneity. Therefore, BBO provides an attractive solution for various non-linear optical applications like OPO, OPA, OPCPA and other. As a result of large thermal acceptance bandwidth, high damage threshold and small absorption BBO well suits for frequency conversion of high peak or average power laser radiation. The large spectral transmission range as well as phase matching, especially in UV range, makes BBO perfectly suitable for frequency doubling of Dye, Ar ion and Copper vapour laser radiation, effective cascade harmonic generation (Frequency doublers, triplers, parametric amplifiers and wave mixers) of wide spread Nd:YAG as well as of Ti:Sapphire and Alexandrite laser radiation. Both angle tuned Type 1 (oo-e) and Type 2 (eo-e) of phase matching can be obtained increasing a number of advantages for different applications.

Standard specifications

Transparency range: 220-2600nm
Surface quality: 10/5 scratch/dig
Flatness at L=633nm: L /6
Parallelism: 10 arc sec
Perpendicularity: <5 arc min
Optical damage threshold, GW/cm ² : >5, t=10ns, @1064nm
Maximum available aperture: 10x10 mm
Maximum length: 15 mm
Aperture tolerance: +0.1/-0 mm
Length tolerance: +0.1/-0 mm

Various specifications KTP, KTA, KDP, BBO, LBO, GaSe, AgGaS₂, AgGaSe₂, LiIO₃, LiNbO₃ or other crystals are available on request.

When Ordering please specify

Application: [e.g. SHG@1064nm; OPO@532nm; DFG@(1064nm & 532nm), etc]
Orientation theta and phi degrees in range of 0-90 deg
Phase Matching: I Type (e-oo) or II Type (e-oe)
Description of AR coatings on Side 1 and Side 2

Code	Name	Material	For	Height (mm)	Width (mm)	Length (mm)	Theta	Phi	Application	Coating	Price	Currency
NLC9	Nonlinear Crystal	BBO	Nd:YAG laser	3	3	7	22.8	90	SGH	AR @ 1064 + 532 nm	114,000	JPY
NLC12	Nonlinear Crystal	BBO	Nd:YAG laser	3	3	7	47.7	90	THG	AR @ 1064 + 532 nm/1064 + 532 + 266	118,500	JPY
NLC8	Nonlinear Crystal	BBO	Nd:YAG laser	4	4	7	22.8	90	SGH	AR @ 1064 + 532 nm	162,000	JPY
NLC14	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.05	48	90	SGH	AR(230-350)/AR(460-700)nm	186,000	JPY
NLC13	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.05	29.18	0	SGH	AR @ 800 + 400 nm	183,000	JPY
NLC18	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.15	29.18	0	SGH	AR @ 800 + 400 nm	162,000	JPY
NLC17	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.2	44.5	90	THG	AR @ 800 + 400 nm/ 800 + 400 + 266 nm	138,000	JPY
NLC16	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.25	41.7	0	SGH	AR @ 800 + 400 nm	132,000	JPY
NLC19	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	0.5	40	90	THG	AR @ 800 + 400 nm/ 800 + 400 + 266 nm	156,000	JPY
NLC20	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	1	29.18	0	SGH	AR @ 800 + 400 nm	126,000	JPY
NLC15	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	2	39	90	SGH	AR @ 800 + 400 nm	114,000	JPY
NLC5	Nonlinear Crystal	BBO	Nd:YAG laser	5	5	3	22.8	90	SGH	AR @ 1064 + 532 nm	129,000	JPY
NLC6	Nonlinear Crystal	BBO	Nd:YAG laser	5	5	4	22.8	90	SGH	AR @ 1064 + 532 nm	148,500	JPY
NLC22	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	6	29.18	0	SGH	AR @ 800 + 400 nm	174,000	JPY
NLC7	Nonlinear Crystal	BBO	Nd:YAG laser	5	5	7	22.8	90	SGH	AR @ 1064 + 532 nm	207,000	JPY
NLC21	Nonlinear Crystal	BBO	Ti:Sapphire laser	5	5	10	29.18	0	SGH	AR @ 800 + 400 nm	234,000	JPY
NLC3	Nonlinear Crystal	BBO	Nd:YAG laser	6	6	6	22.8	90	SGH	AR @ 1064 + 532 nm	237,000	JPY
NLC11	Nonlinear Crystal	BBO	Nd:YAG laser	6	6	6	47.7	90	THG	AR @ 1064 + 532 nm/1064 + 532 + 266	241,500	JPY
NLC4	Nonlinear Crystal	BBO	Nd:YAG laser	6	6	12	22.8	90	SGH	AR @ 1064 + 532 nm	363,000	JPY
NLC23	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.05	29.18	0	SGH	AR @ 800 + 400 nm	204,000	JPY
NLC24	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.05	42.4	0	SGH	AR @ 800 + 400 nm	204,000	JPY
NLC26	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.05	44.3	0	THG	AR @ 800 + 400 nm	204,000	JPY
NLC25	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.1	29.18	0	SGH	AR @ 800 + 400 nm	177,000	JPY
NLC27	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.15	44.3	0	THG	AR @ 800 + 400 nm	165,000	JPY
NLC28	Nonlinear Crystal	BBO	Ti:Sapphire laser	7	8	0.25	44.3	0	THG	AR @ 800 + 400 nm	147,000	JPY
NLC29	Nonlinear Crystal	BBO	Ti:Sapphire laser	10	10	4	27	0	OPA	AR @ 800 / 1000-2500 nm	378,000	JPY
NLC2	Nonlinear Crystal	BBO	Nd:YAG laser	10	10	4	22.8	90	SGH	AR @ 1064 + 532 nm	372,000	JPY
NLC10	Nonlinear Crystal	BBO	Nd:YAG laser	10	10	4	47.7	90	THG	AR @ 1064 + 532 nm/1064 + 532 + 266	381,000	JPY
NLC1	Nonlinear Crystal	BBO	Nd:YAG laser	10	10	5	22.8	90	SGH	AR @ 1064 + 532 nm	417,000	JPY

3.1.2. KTP Nonlinear Crystals



Efficient frequency conversion and Large non-linear optical coefficients
Wide angular bandwidth and small walk-off angle
Broad temperature and spectral bandwidth
Low cost compare with BBO and LBO

Single crystal Potassium Titanyl Phosphate is an excellent non-linear crystal.

It exhibits high optical quality, broad transparent range, relatively high effective SHG coefficient (about 3 times higher than that of KDP), rather high optical damage threshold, wide acceptance angle, small walk-off and type I and type II non-critical phase-matching (NCPM) in a wide wavelength range. KTP is the most commonly used material for frequency doubling of Nd:YAG lasers and other Nd-doped lasers, particularly at the low or medium power density.

Standard specifications
Transparency range: 350-4500nm
Surface quality: 10/5 scratch/dig
Flatness at L=633nm: L /6
Parallelism: 10 arc sec
Perpendicularity: <5 arc min
Optical damage threshold, MW/cm ² : >500, t=10ns, @1064nm
Maximum available aperture: 15x15 mm
Maximum length: 25 mm
Aperture tolerance: +0.1/-0 mm
Length tolerance: +0.1/-0 mm

When Ordering please specify
Application: [e.g. SHG@1064nm; OPO@532nm; DFG@(1064nm & 532nm), etc]
Orientation theta and phi degrees in range of 0-90 deg
Phase Matching: I Type (e-oo) or II Type (e-oe)
Description of AR coatings on Side 1 and Side 2

Code	Name	Material	For	Height (mm)	Width (mm)	Length (mm)	Theta	Phi	Application	Coating	Price	Currency
NLC33	Nonlinear Crystal	KTP		3	3	5					81,000	JPY
NLC34	Nonlinear Crystal	KTP		3	3	10				AR @ 1064 + 532 nm	108,000	JPY
NLC35	Nonlinear Crystal	KTP		3	3	20				AR @ 1064 + 532 nm	156,000	JPY
NLC36	Nonlinear Crystal	KTP		4	4	10				AR @ 1064 + 532 nm	126,000	JPY
NLC37	Nonlinear Crystal	KTP		4	4	20					171,000	JPY
NLC38	Nonlinear Crystal	KTP		5	5	20					204,000	JPY
NLC39	Nonlinear Crystal	KTP		10	10	2					186,000	JPY
NLC40	Nonlinear Crystal	KTP		10	10	5			SGH	AR @ 1064 + 532 nm	246,000	JPY

3.1.3. LBO Nonlinear Crystals



Broad transparency range from 160 nm to 2600 nm
Relatively large effective SHG coefficient (about three times that of KDP)
High damage threshold (18.9 GW/cm² for a 1.3 ns laser at 1053nm)
Wide acceptance angle and small walk-off
Type I and Type II non-critical phase matching in a wide wavelength range

LBO's high damage threshold, wide acceptance angle, good thermal stability and wide transmission range make it ideal for frequency doubling of high power lasers.

It is unique in many aspects, especially its wide transparency range, moderately high non-linear coupling, high damage threshold and good chemical and mechanical properties. Its transmission range is from 210nm to 2300nm. LBO allows temperature-controllable non-critical phase-matching (NCPM) for 1000-1300nm, Type I SHG, and also provides room temperature NCPM for Type II SHG at 800-1100nm. It possesses a relatively large angular acceptance bandwidth, reducing the beam quality requirements for source lasers.

Standard specifications
Transparency range: 160-2800nm
Orientation accuracy of cut angle: 30 arc min
Surface quality: 10/5 scratch/dig
Flatness at L=633nm: L /6
Parallelism: 10 arc sec
Perpendicularity: <5 arc min
Optical damage threshold, GW/cm ² : >10, t=1ns, @1064nm
Maximum available aperture: 10x10 mm
Maximum length: 15 mm
Aperture tolerance: +0.1/-0 mm
Length tolerance: +0.1/-0 mm

When Ordering please specify
Application: [e.g. SHG@1064nm; OPO@532nm; DFG@(1064nm & 532nm), etc]
Orientation theta and phi degrees in range of 0-90 deg
Phase Matching: I Type (e-oo) or II Type (e-oe)
Description of AR coatings on Side 1 and Side 2

Code	Name	Material	For	Height (mm)	Width (mm)	Length (mm)	Theta	Phi	Application	Coating	Price	Currency
NLC30	Nonlinear Crystal	LBO	for Nd:YAG laser	3	3	10			SGH	AR @ 1064 + 532 nm	108,000	JPY
NLC31	Nonlinear Crystal	LBO	for Nd:YAG laser	5	5	5			SGH	AR @ 1064 + 532 nm	147,000	JPY
NLC32	Nonlinear Crystal	LBO	for Nd:YAG laser	8	8	5			SGH	AR @ 1064 + 532 nm	228,000	JPY

3.1.4. AgGaS2 Nonlinear Crystals

Silver Thiogallate has been demonstrated to be an efficient frequency doubling crystal for infrared radiation.

This crystal has a high non-linear coefficient, high damage threshold, and a wide transmission range. It also has low optical absorption and scattering, low wavefront distortion. Among commercially available crystals, AgGaS₂ has the highest figure of merit for non-linear interactions in the near and deep infrared. Silver Selenogallate (AgGaSe₂) has band edges at 730 and 1800nm. Its useful transmission range lying within 916nm and wide phase matching provide excellent potential for OPO applications when pumped by variety of currently available lasers. Tuning within 2512nm was obtained when pumped by Ho:YLF laser at 2050nm; It has also been shown as an excellent crystal for non-linear three-wave interactions.

Standard specifications
Transparency range: 500-1200nm
Orientation accuracy of cut angle: 30 arc min
Surface quality: 20/10 scratch/dig
Flatness at L=633nm: L/4
Parallelism: 10 arc sec
Perpendicularity: <5 arc min
Optical damage threshold, GW/cm ² : >0.05, t=10ns, @1064nm
Maximum available aperture: 15x15 mm
Maximum length: 15 mm
Aperture tolerance: +0.1/-0 mm
Length tolerance: +0.1/-0 mm

When Ordering please specify
Application: [e.g. SHG@1064nm; OPO@532nm; DFG@(1064nm & 532nm), etc]
Orientation theta and phi degrees in range of 0-90 deg
Phase Matching: I Type (e-oo) or II Type (e-oe)
Description of AR coatings on Side 1 and Side 2

Code	Name	Material	For	Height (mm)	Width (mm)	Length (mm)	Theta	Phi	Application	Coating	Price	Currency
NLC41	Nonlinear Crystal	AgGaS2		5	5	1.3	39	0	DFG	AR @ 1,2 – 2,4 / 2,4 – 12 mkm	117,000	JPY
NLC42	Nonlinear Crystal	AgGaS2		5	5	2	42	0	DFG	AR @ 1,2 – 2,2 / 4 – 14 mkm	126,000	JPY
NLC43	Nonlinear Crystal	AgGaS2		5	5	3	39	0	DFG	AR @ 1,2 – 2,4 / 2,4 – 12 mkm	132,000	JPY
NLC48	Nonlinear Crystal	AgGaS2		6	6	1	39		DFG	AR@(s1200-1480,p1650-2250nm)/AR@2.6-10µm,	189,000	JPY
NLC47	Nonlinear Crystal	AgGaS2		9	7	5	45		DFG	AR@1.064-1.8 micron / 2.4-11 micron	312,000	JPY
NLC49	Nonlinear Crystal	AgGaS2		10	10	2	41		DFG	1,8 µm – 2,60 µm -> 5,8 µm + broad AR coating	207,000	JPY
NLC50	Nonlinear Crystal	AgGaS2		10	10	5	45	45	OPO	AR@1.064 um&AR@1.2-1.45um on the two faces	597,000	JPY
NLC44	Nonlinear Crystal	AgGaS2		10	10	10	45	0		AR@1064nm +1450-1170nm on both faces	1,047,000	JPY
NLC46	Nonlinear Crystal	AgGaS2		10	10	20	33.5			1,92 µm – 2,39 µm -> 10 µm 1,68 µm – 2,09 µm -> 8,46 µm + broad AR coating,	1,671,000	JPY
NLC45	Nonlinear Crystal	AgGaS2		12	8	20	42		DFG	1,8 µm – 2,60 µm -> 5,8 µm + broad AR coating,	1,641,000	JPY

3.1.5. AgGaSe2 Nonlinear Crystals

Code	Name	Material	For	Height (mm)	Width (mm)	Length (mm)	Theta	Phi	Application	Coating	Price	Currency
NLC52	Nonlinear Crystal	AgGaSe2		5	5	2	55			AR@1200-2200nm; S2: AR@4000-14000nm	144,000	JPY
NLC53	Nonlinear Crystal	AgGaSe2		8.5	5	1	52			uncoated	228,000	JPY
NLC51	Nonlinear Crystal	AgGaSe2		10	10	2	48.8		DFG	1.87 μ m – 2.47 μ m -> 7,7 μ m + broad AR coating	268,500	JPY
NLC54	Nonlinear Crystal	AgGaSe2		12	10	20	48.8		DFG	1.87 μ m – 2.47 μ m -> 7,7 μ m + broad AR coating	2,427,000	JPY