



GAMDAN OPTICS

## Beta-Barium Borate ( $\beta$ -BaB<sub>2</sub>O<sub>4</sub>)



Gamdan grows boules (ingots of crystals) using specialized processes that have been refined over the past 30 years. Even the crystal synthesizing equipment is custom-engineered by Gamdan scientists.

Beta-Barium Borate (BBO) is an excellent non-linear crystal for frequency-doubling (SHG) of Visible and Near IR laser light, OPO/OPG/OPA pumped by ultrafast pulses of wavelengths in the Near IR to UV, and sum-frequency mixing (SFM) into the Visible to the deep UV. BBO is the only practical crystal for use below 500nm in SHG and SFM.

BBO crystal has broad tunability, high damage threshold, and high efficiency. BBO's small acceptance angle requires a very good beam quality and its large walkoff results in output beams that are very elliptical or slit-like. Type I is usually much more efficient than type II operation. BBO cannot be used for NCPM (temperature tuned) application. BBO is very good for tunable laser sources, such as ultrafast Ti:Sapphire or dye lasers. It is also widely used for SHG, 3HG, 4HG, and autocorrelation of femtosecond and picosecond Ti:Sapphire lasers; SHG, 3HG, 4HG, 5HG of YAG lasers at 1064nm and 1320nm to yield output of 212-660nm; SHG of tunable dye or solid-state laser sources from 410-750nm to yield output of 205-375nm, SFM of dye laser and YAG harmonics to yield output of 189-400nm; DFM (difference-frequency mixing) from the Visible to the IR range up to over 3000nm; OPO pumped with SHG or 3HG of YAG or Ti:Sapphire with an output range of 400-3000; intracavity SHG of Argon ion lasers (488nm, 514nm) or Copper vapor lasers (510nm, 578nm).

### About GAMDAN

GAMDAN Optics synthesizes, custom designs and precision manufactures NLO crystals. Our exclusive **CrystalExpress**<sup>SM</sup> delivers California-grown crystals with exceptional quality in only 10 business days—the fastest in the industry.\*

\*As of January 2008 per GAMDAN market survey. Precision cut and polish BBO and KTP crystals; coating times will vary.

# Beta-Barium Borate

## Crystal Structural and Physical Properties

Crystal Structure	Trigonal, space group $R_{3c}$
Cell Parameters	$a = b = 12.532\text{\AA}$ , $c = 12.717\text{\AA}$ , $Z = 6$
Melting point	$1095 \pm 5^\circ\text{C}$
Transition temperature	$925 \pm 5^\circ\text{C}$
Optical homogeneity	$\delta n \sim 10^{-6}/\text{cm}$
Mohs hardness	4
Density	$3.85 \text{ g/cm}^3$
Absorption coefficient	$< 0.1\%/ \text{cm}$ (at 1064nm)
Specific heat	$1.91 \text{ J/cm}^3 \times \text{K}$
Hygroscopic susceptibility	low
Thermal expansion coefficients	$a, 4 \times 10^{-6}/\text{K}$ ; $c, 36 \times 10^{-6}/\text{K}$
Thermal conductivity	$\perp c, 1.2 \text{ W/m/K}$ ; $//c, 1.6 \text{ W/m/K}$

## Linear Optical Properties

Transparency range	189-3500nm
Refractive indices:	$n_e = 1.5425$ , $n_o = 1.6551$
at 1064nm	$n_e = 1.5555$ , $n_o = 1.6749$
at 532nm	$n_e = 1.6146$ , $n_o = 1.7571$
at 266nm	
Therm-optic coefficients	$dn_o/dT = -9.3 \times 10^{-6}/^\circ\text{C}$ $dn_e/dT = -16.6 \times 10^{-6}/^\circ\text{C}$
Sellmeier Equations ( $\lambda$ in mm)	
	$n_o^2(\lambda) = 2.7359 - 0.01354\lambda^2 + 0.01878/(\lambda^2 - 0.01822)$
	$n_e^2(\lambda) = 2.3753 - 0.01516\lambda^2 + 0.01224/(\lambda^2 - 0.01667)$

## Nonlinear Optical Properties

Phase-matchable output wavelength	189 - 1750nm
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	$\gamma_{11} = 2.7 \text{ pm/V}$ , $\gamma_{22}$ , $\gamma_{31} < 0.1\gamma_{11}$
Half-wave voltage	48 KV (at 1064nm)
Damage threshold	
at 1064nm	$5 \text{ GW/cm}^2$ (10 ns); $10 \text{ GW/cm}^2$ (1.3 ns)
at 532nm	$1 \text{ GW/cm}^2$ (10 ns); $7 \text{ GW/cm}^2$ (250 ps)

## BBO Typical Specifications

Thin crystals:  $5 \times 5 \times (0.05-3) \text{ mm}^3$ ,  $10 \times 10 \times (0.1-3) \text{ mm}^3$

Regular sizes:  $4 \times 4 \text{ mm}^2$  to  $20 \times 20 \text{ mm}^2$  in diameter, 3 - 20 mm in length

Different cuts, sizes and AR coatings are available upon request.

BBO is hygroscopic. In application, protective coating or AR coating or crystal housing is usually recommended.



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