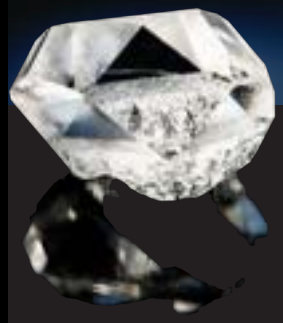

How to Select and Specify
A NON-LINEAR OPTICAL CRYSTAL

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INTRODUCTION
THE PROCESS OF NLO CRYSTAL SELECTION AND SPECIFICATION

A key task faced by engineers using nonlinear crystals is the correct selection and effective specification of the appropriate NLO crystal for a particular laser design or application. GAMDAN Optics supports customers in successfully completing all the steps in this selection and specification process.

Here is a brief outline of the essential steps in choosing and specifying a nonlinear crystal.

I. Based upon the optical requirements, the type of crystal (BBO, KTP, LBO, etc.) is selected.
II. Based upon the economic and physical constraints, the bulk quality properties of the crystal are determined.
III. The specific mechanical shape and surface quality of the crystal are specified.
IV. The crystal's optical coatings are selected.
V. The packaging and handling procedures for the crystal are specified.

NLO CRYSTAL SELECTION AND SPECIFICATION

NLO CRYSTAL TYPE SELECTION

The selection of NLO crystals usually is based on performance modeling. Nonlinear interactions can be modeled using the excellent software package SNLO. This software is free and available at: http://www.as-photonics.com/SNLO.

Arlee V. Smith wrote SNLO, and he has continued to maintain and update the program. The SNLO software includes data on the chemical and physical properties of many commonly used NLO crystals. At this stage, designers should take into account the constraints on the nonlinear crystal such as the positioning accuracy, available space, beam aperture, operating temperature, as well as the tolerances available for these parameters. The designer also needs to understand the parameters of the desired input and output beam(s) such as the wavelength, polarization, spectral width, beam divergence, beam quality, pulsed or continuous operation, and pulse width and energy if applicable.

These constraints and operating conditions lead to trade-offs between the different candidate nonlinear materials under evaluation. The goal is to determine what nonlinear materials will give a suitable combination of resistance to laser damage, nonlinear conversion efficiency, and output beam quality.

It is often useful to have an intuitive understanding of how the efficiency of a nonlinear process scales for different crystal materials and with the basic parameters like crystal length and the peak power of the incident beam[1]. However, the nonlinear conversion efficiency is very sensitive to the details of the nonlinear conversion process, such as birefringent walkoff[2] and rough estimates of nonlinear conversion efficiency will often only give an upper bound on the conversion efficiency.

[1] [www.gamdan.com/blog/estimates-of-second-harmonic-generation-shg-efficiency]
[2] [www.gamdan.com/blog/introduction-to-walkoff],

NLO CRYSTAL TYPE SELECTION

Actual experimental results may fall short of modeled results if the beam quality, beam overlap, or phase matching is imperfect. For each candidate crystal, various parameters and scenarios can be tested using SNLO or other software until the optimal crystal type is identified. Frequently, several types are carried further until subsequent considerations eliminate options.

NLO CRYSTAL QUALITY DETERMINATION
CRYSTAL GROWTH

Good bulk crystal quality requires preventing the presence of crystal defects, inclusions, and impurities during the crystal growth process. The more stringent the requirements, the more refined the growth process must be, and the higher the cost. For some users of nonlinear crystals, considerations of production location (US vs. foreign), production traceability, and the quality control system of the crystal's grower and fabricator are critical. GAMDAN Optics, Inc. keeps quality control records as part of its production system.

NLO CRYSTAL DESIGN
CRYSTAL SHAPE FABRICATION

Once the type of crystal is chosen, and the bulk material quality (thus its source) is determined, the actual crystal dimensions are specified. These specifications include the dimensions (length, width, and height), shape (which can include wedging or even Brewster cut surfaces), bevel size, bevel angle, and the crystal orientation. GAMDAN Optics, Inc. maintains tight tolerances on crystal dimensions, among the best in the industry.

NLO CRYSTAL COATING
CRYSTAL SURFACE FABRICATION

The surface quality and the quality and type of the optical coatings have a profound impact on the damage threshold and lifetime of the crystal. Damage can often be repaired by "repolishing", however, damage is a reliability failure. Avoiding damage is extremely valuable, so having an excellent surface is critical.

Specification of the surface quality involves defining the acceptable number of scratches, digs, and chips; the tolerances for parallelism and perpendicularity of the faces; surface flatness and surface roughness. The coating specification needs to identify the use environment. It also needs to call out the required transmission (or reflectivity) for all the wavelengths of operation. Furthermore, the beam characteristics at each wavelength need to be specified including the peak powers, average powers, polarizations, and beam diameters.

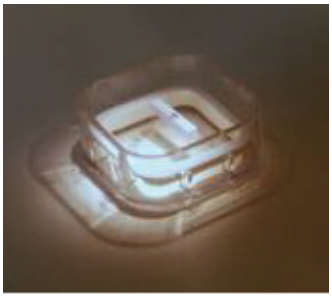
If the beams are pulsed, then the pulsewidths and repetition rates need to be specified as well. Some common types of coatings are broadband, dual wavelength band, or single wavelength band antireflection coatings.

There are many possible choices of coating designs and coating materials.

GAMDAN Optics, Inc. provides exceptional surface quality and coatings that lead to long lifetimes and high damage thresholds.

NLO CRYSTAL PACKAGING

To best preserve the quality of the crystal, the packaging must control the environment and protect crystals from physical or chemical damage or other degradation. For example, control of moisture and contamination are required, as well as protection from mechanical shock, vibration, and accidental optical surface contact.



GAMDAN OPTICS, INC.

GAMDAN Optics, Inc., in San Jose, CA, grows and fabricates top quality nonlinear optical (NLO) crystals such as Beta Barium Borate (BBO), Lithium Triborate (LBO), and Potassium Titanyl Phosphate (KTP). These crystals are crucial for the generation of high power visible and UV laser light, and some of these crystals can be used for other applications such as electro-optical switches.

GAMDAN Optics puts good quality FIRST, and has a rigorous Quality system based on ISO guidelines. GAMDAN Optics with the R&D departments of customers to help them create their new products. Integrity is one of the core values of GAMDAN Optics, and GAMDAN Optic's operating practices provide confidentiality and IP security for customer interactions.

Typical GAMDAN Optics LBO has fully callibrated absorption of < 10 ppm/cm. (Please contact us to discuss the details of the calibration) This was measured by photo-thermal common-path interferometry (PCI) at the testing laboratory of Stanford Photo-Thermal Solutions. This low absorbance coupled with excellent polishing and good optical coatings contributes to long operational life for Gamdan LBO.

GAMDAN Optics BBO crystals are also high quality and can be fabricated in large sizes. GAMDAN Optics KTP, grown by its partners using both flux and hydrothermal methods, is also of exceptional purity and uniformity.

PRODUCTS AND SERVICES

GAMDAN Optics offers nonlinear crystals including LBO, BBO, and KTP. GAMDAN Optics also fabricates crystals and provides exceptional surface quality. GAMDAN Optics offers coated or uncoated parts. Applications of Gamdan Optics' crystals include harmonic generation, sum frequency generation, optical parametric oscillation, and Q-switching.