RAICOL CRYSTALS

An OXIDE company

NONLINEAR CRYSTALS PIONEERS

RAICOL CRYSTALS
An OXIDE company

ABOUT RAICOL CRYSTALS

Raicol Crystals is an Israeli company that specializes in high-quality nonlinear crystals and electro-optic devices for laser systems in the medical, military, industrial, and aerospace industries.

The company has more than 90 employees, including qualified technicians and production personnel, marketing and sales professionals, a management team with extensive experience, and a strong scientific team with experience translating academic research into commercial product development.

In January 2023, Raicol Crystals was acquired by the Japanese company OXIDE Corporation. OXIDE specializes in the research and manufacturing of single crystals, optical devices, and lasers. Together with OXIDE, Raicol Crystals offers a one-stop-shop for high-end products as well as special customized solutions for customers' success.

Our products

Electro Optical Cells: RTP, iRTP, KRTP, BBO

Frequency conversion elements:

- KTP for SHG and OPO
- HGTR KTP for High Power SHG
- Super Polished LBO for SHG and THG
- BBO for frequency conversion
- PPKTP / APKTP / PPLN For SPDC & Quantum Applications

Raicol Ltd. has ISO 9001 certification, meeting high global standards for quality control. We are also NASA certified.

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OUR PRODUCTION SITE

Raicol Crystals - From growth to optical assembly.

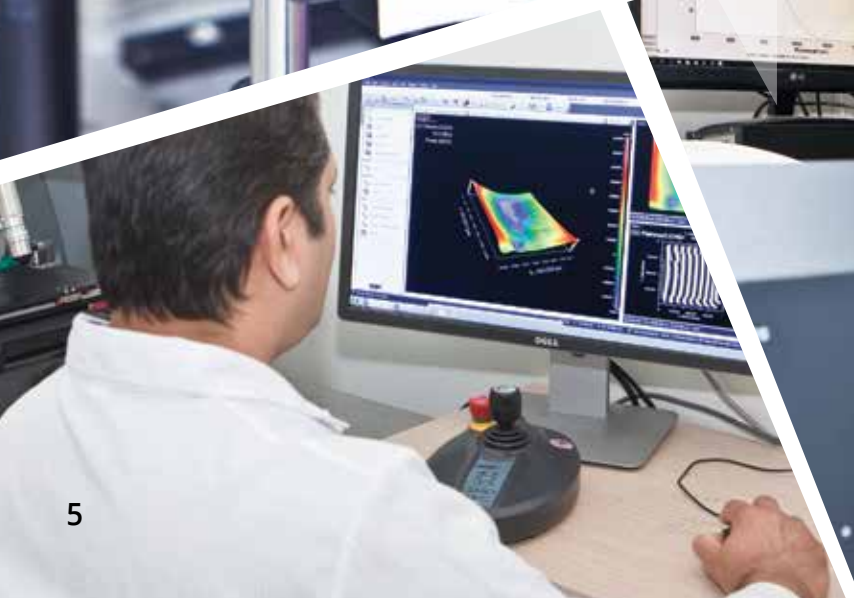
We have a 3,500-square meter facility with over 200 crystal growth stations equipped with the latest technology:
Our proprietary growth systems, state-of-the-art cutting and polishing machines, clean rooms, optical coating, unique measurement and testing equipment, and optical assembly capabilities are just some of the things we offer.
Raicol offers a one-stop-shop for all your needs with the highest quality

RAICOL'S IN HOUSE TESTING CAPABILITIES

We have high-end internal testing capabilities:

- Low and high power absorption tests
- Laser Damage Threshold
- Interferometer for roughness and flatness measurments
- XRD
- Spectrophotometer
- Wave Front Distortion
- Microscopy quality tests
- Temperature stability tests

Using advanced equipment and expertise, we are able to achieve maximum quality and reliability for each and every product we manufacture.



RTP EO Cells

RTP belongs to the KTP crystal family. The outstanding Electro-Optical properties of RTP, together with its high damage threshold, make it a perfect solution for high-end laser applications. It is ideal for applications that require advanced characteristics, such as non-hygroscopic, high thermal stability, and high-repetition rates.

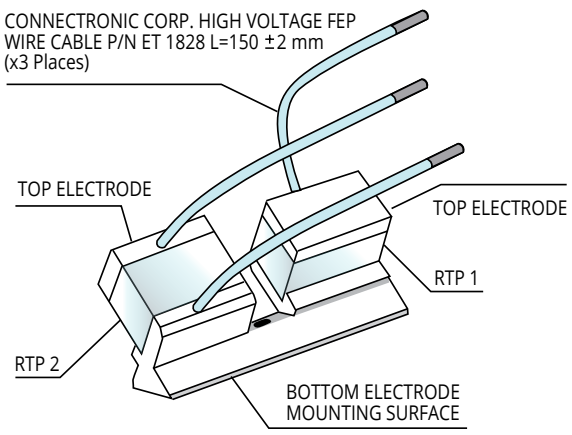
RTP EO Cells are assembled in a thermally compensated double-crystal configuration, in which two matched crystals are placed in line of the propagation axis (X or Y) with one rotated by 90 degrees (general drawing below).

RTP EO cells used for electro-optics applications, RTP crystals offer superior properties for users in the Aerospace, Defense, Medical, Industrial, Civil and Scientific applications.

Common Applications

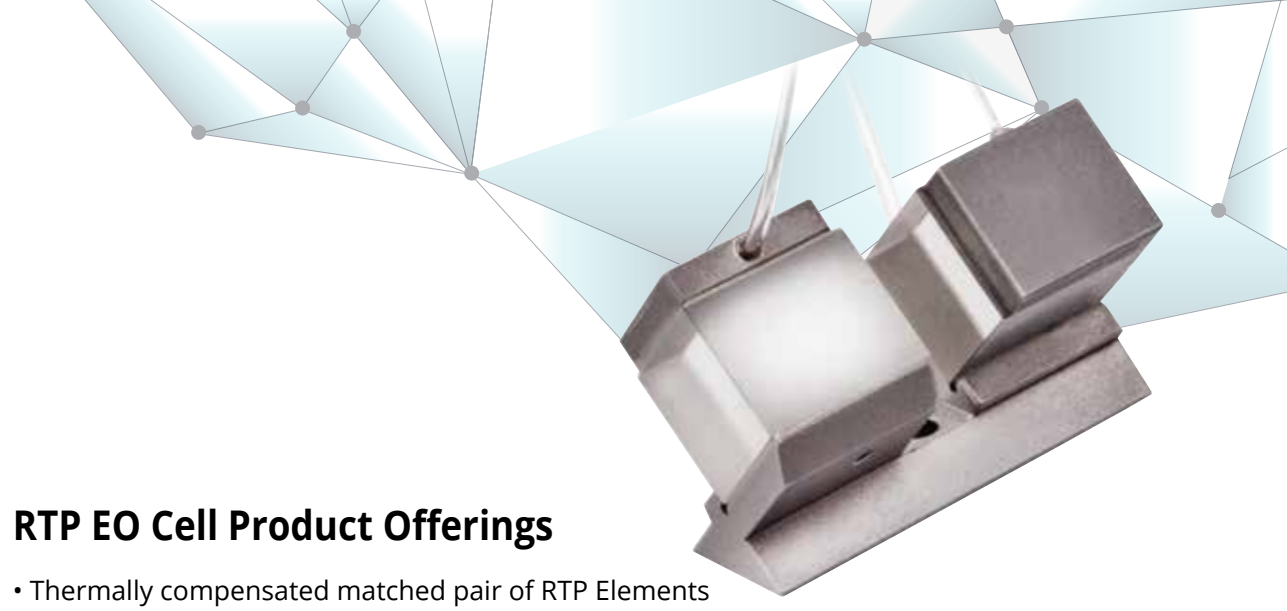
Q Switches **|** Pulse pickers
Phase modulators **|** Amplitude modulators
Cavity dumpers **|** Shutters
Attenuators & Deflectors

RTP EO Cell Structure



Advantages

- Low half-wave voltage for EO Cells to enable a compact design
- Rise time, fall time, and pulse width < 1 ns which enables fast operation
- Designed to operate at a wide temperature stability range (-50° C to 70° C)
- High laser-induced damage threshold (up to 1GW/cm², @1064 nm, 10 ns pulse)
- Minimal ringing, compatible for over 1 MHz repetition rate
- Non-hygroscopic, easy handling, no cover needed
- The best material in the spectral range of 500-3000 nm for electro-optics applications
- Very low absorption losses @1064 nm wavelength
- Extremely high homogeneity: up to 15× 15 mm² EO cells as a standard size



RTP EO Cell Product Offerings

- Thermally compensated matched pair of RTP Elements
- Single RTP Element (used for phase modulators)
- Plug and play, Electro-optical cells assembly (with / without housing)

Typical Specifications for RTP EO Cells

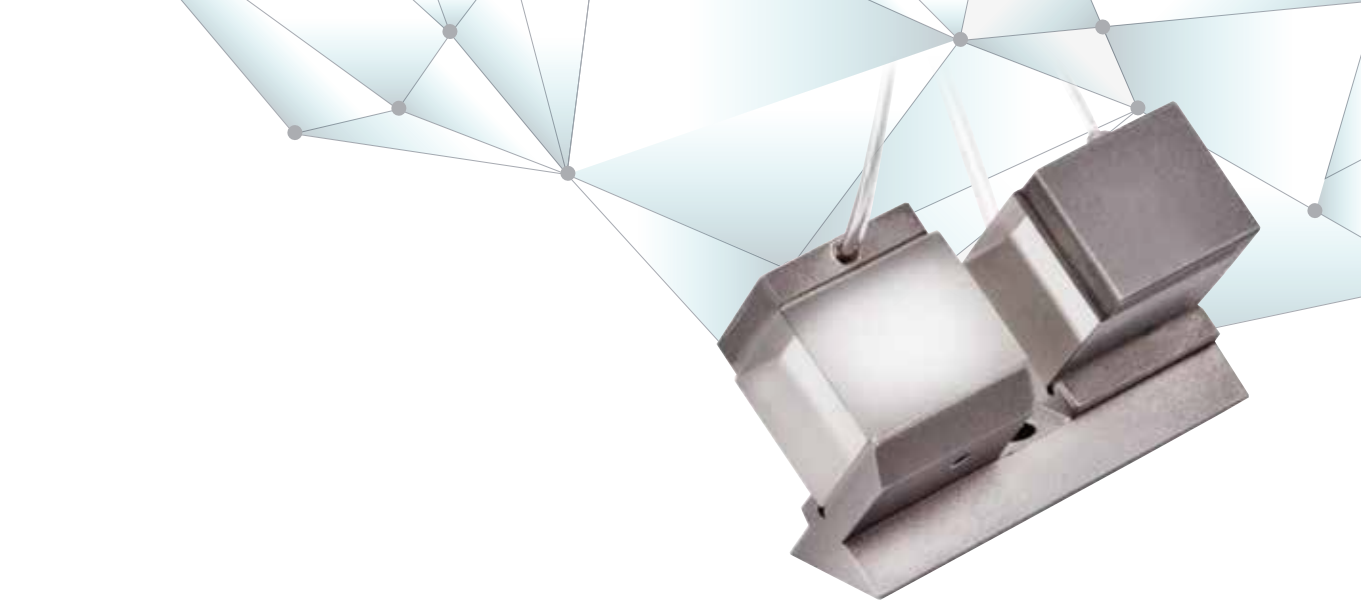
Operational Range	500-3000 nm
Transmission @1064 nm	> 99%
Half Wave Voltage	3.6 kV (for EO Cell size: 9 x 9 x 10 mm²)
Extinction Ratio	Over 30 dB
Clear Aperture	1.5 x 1.5 mm² to 15 x 15 mm²
Crystal Length	Up to 50 mm
Acceptance Angle	< 4 deg.
Standard AR Coating @1064 nm	R < 0.2%
Laser Induced Damage Threshold	Up to 1 GW/cm², @1064 nm, 10 ns pulse or 10J/cm²

Raicol's RTP Benefits

- Low half-wave voltage to enable a compact design
- High Damage Threshold (600MW/cm² in typical value 1GW/cm²)
- High Extinction Ratio (ER) up to 30-35 dB
- No acoustic ringing up to MHz regime
- Wide acceptance angle
- Suitable for Military and Space application due to it's wide temperature stability (-50° C to 70° C)
- Non-hygroscopic material
- Low electrical conductivity – Rise time / fall time < 1ns

EO Cells – Crystals Comparison

Properties	$LiNbO_3$	RTP X-cut
Half Wave Voltage @1064 nm for L=d (kV)	9	8
Dielectric constant Ɛ	27.9	11
Average Power Density (W/cm²)	150	300
Laser Induced Damage Threshold (MW/cm²)	280	> 600
Available Aperture (mm²)	>8x8	2x2 to 15x15
Extinction Ratio (dB)	>23	23-35
Temperature Stability *Pyro electric effect	Not stable at T<-20˚C	-50˚ to 70˚C
Acoustic Ringing	10 Khz	>1 MHz
Hygroscopic	No	No
Mechanically Stable	Medium	Good



RTP Y-cut	KRTP	KD*P	BBO
6.5	7	9	48
11	11	48	8
200	800	250	>1,000
600	600	500	>1,000
2x2 to 6x6	2x2 to 6x6	5x5 to 20x20	1x1 to 12x12
23-30	23-30	23-30	>30
-50˚ to 70˚C	-50˚ to 70˚C	Not stable	Good
>1 MHz	>1 MHz	10 KHz	25 KHz
No	No	Yes	Yes
Good	Good	Low	Good

iRTP
Pockels Cell

Raicol's new iRTP Pockels Cell (PC) is the first product that brings the advantages of RTP to the EO mass market. iRTP PC is a modified version of Raicol's RTP, designed specifically for industrial laser applications. Raicol's iRTP PC is a standard off-the-shelf solution that offers high performance EO cells at the price of standard industry PCs.

Raicol's iRTP PC Features

- High laser damage threshold
- Fast rise-fall time and pulse width
- Non-hygroscopic material
- Low absorption losses
- No acoustic ringing (up to at least 350kHz)
- Thermal stability over a wide operational temperature range (10ºC –50ºC)

Raicol's iRTP PC Specifications:

IRTP Parameters	iRTP 6	iRTP 8	iRTP 10
Aperture	6x6mm	8x8mm	10x10mm
Capacitance	< 6pf		
Quarter wave voltage (@1064)	3.3 KV		
Optical transmission	>99%		
ER (@1064)	≥ 27 dB		
Damage threshold	typically, > 1GW/cm^2		
Alignment access	1 axis aligmnent		
Housing Dimensions	Round: Θ35 mm, Length 35 mm. (there is a 1" design). Square: 35mmx35mmx35mm		
Rise time	<1 ns		
Thermal stability	10 – 50 Deg.		

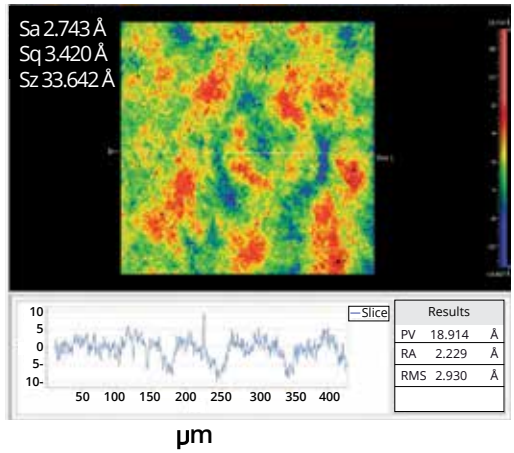
LBO Crystals

LBO (Lithium Triborate LiB_3O_5) is a nonlinear optical crystal ideally suitable for various nonlinear optical applications. LBO crystals combine wide transparency, relatively high nonlinear coupling, high damage threshold and good chemical and mechanical properties.

Special Advantages of our LBO

- Super polished elements for excellent surface quality: roughness ≤ 3Å RMS and scratch dig 2/1
- Very low bulk absorption: up to 2ppm/cm @1064nm
- Crystal size up to 50x50 mm^2 and maximum length of 50 mm
- Strict quality control

ROUGHNESS MEASUREMENTS BY ZYGO INTERFEROMETER



Our LBO features

- Wide transparency range (160nm – 2600nm)
- Relatively high nonlinear coefficient
- High damage threshold
- Type I and II phase matching in a wide wavelength range
- High optical homogeneity
- Wide acceptance angle and small walk-off angle

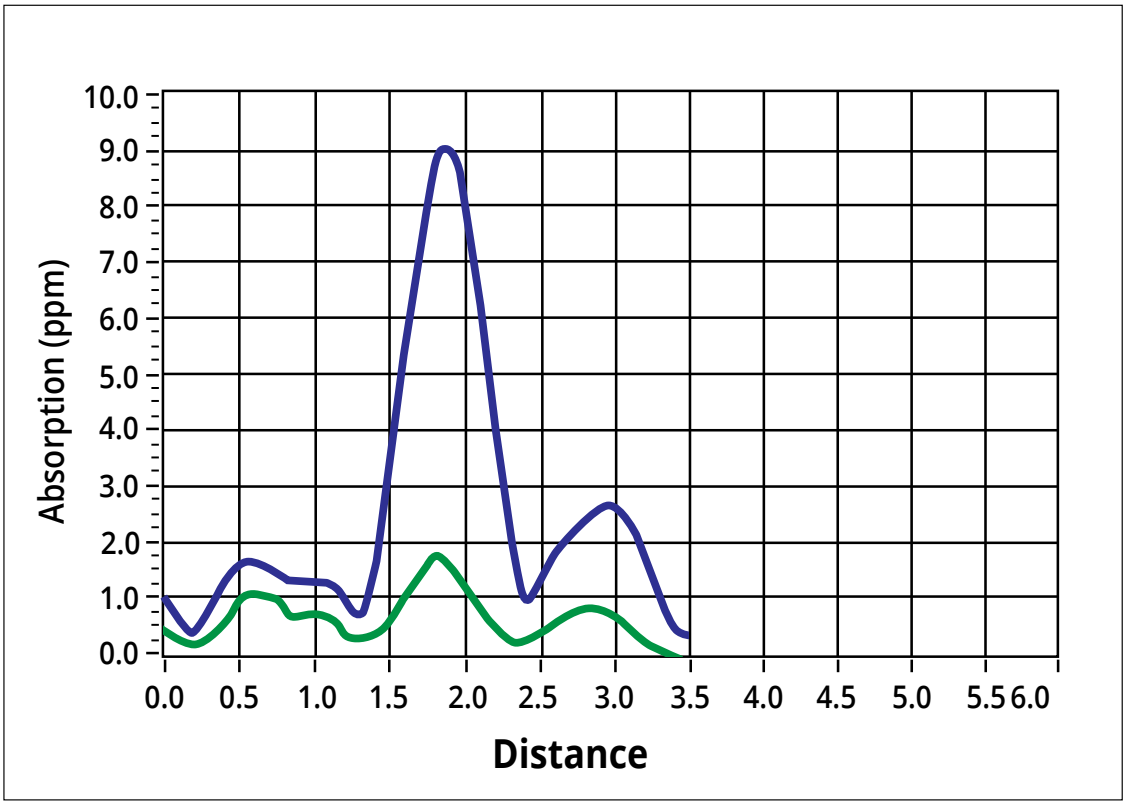
Common Applications

- Second and third harmonic generation of high power diode pumped Nd:YAG and Nd:YLF lasers, Alexandrite, Ti:Sapphire, Dye lasers and ultrashort pulse lasers
- OPCPA

Typical Specifications for LBO

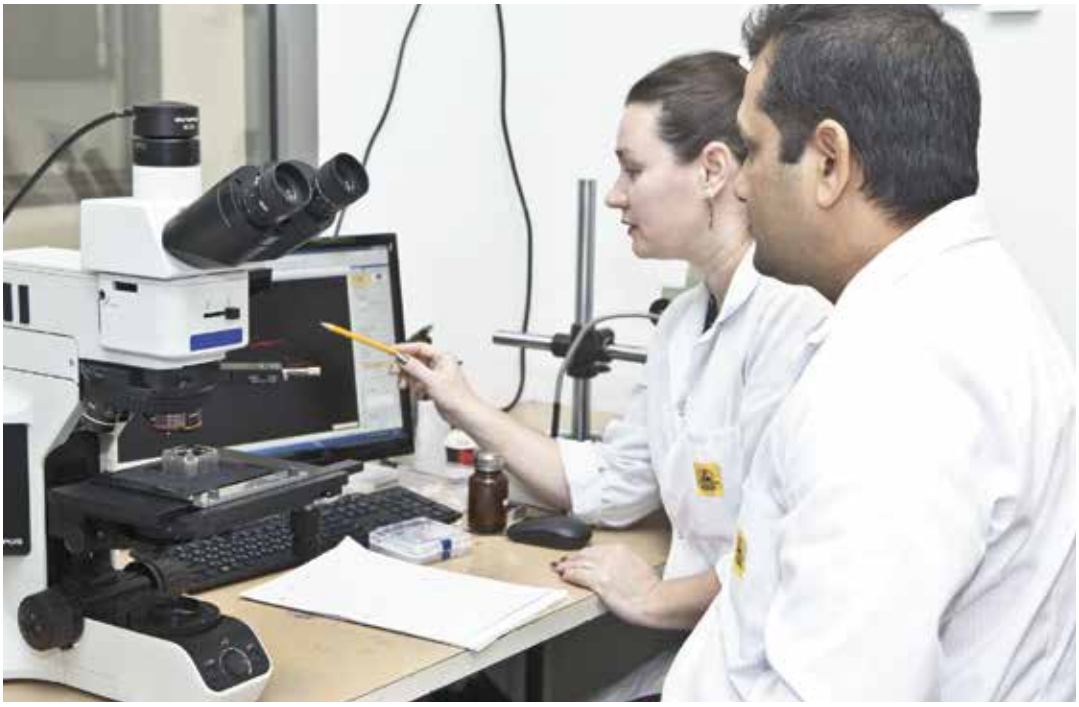
Apertures	Up to 60x60 mm²
Length	Up to 70 mm along x axis
Flatness	Up to λ/10 @1064nm
Roughness	≤3Å RMS
Parallelism	Up to 5 arc sec.
Perpendicularity	Up to 5 arc min.
Scratch/Dig	2/1 up to 0/0 per custom demand
AR Coatings	Dual band R < 0.1%
Absorption Coefficient	<Bulk (1064nm) =2-4 ppm/cm <Surface (1064nm) = 1-2 ppm <Bulk (532nm) = 8ppm/cm <Surface (532nm) = 1-2 ppm
Wave Front Distortion	λ/8 @633 nm
Laser induced Damage Threshold	2500 MW/cm² @1064 nm 1000 MW/cm² @532 nm 500 MW/cm² @355 nm For 10 ns pulses @ 10 Hz

Surface absorption performed @532nm on LBO crystal AR coated @1064/532nm



Graph clearly highlights that surface absorption at 532nm performed on coated LBO Superpolished crystal (roughness ≤3Å) absorbs 4 times less than standard polished coated LBO crystal (roughness of ~10Å).

Based on this difference, LBO Superpolished crystals made at Raicol should exhibit longer lifetime, and withstand higher powers.



KTP Crystals

KTP (Potassium Titanyl Phosphate, KTIOPo4)

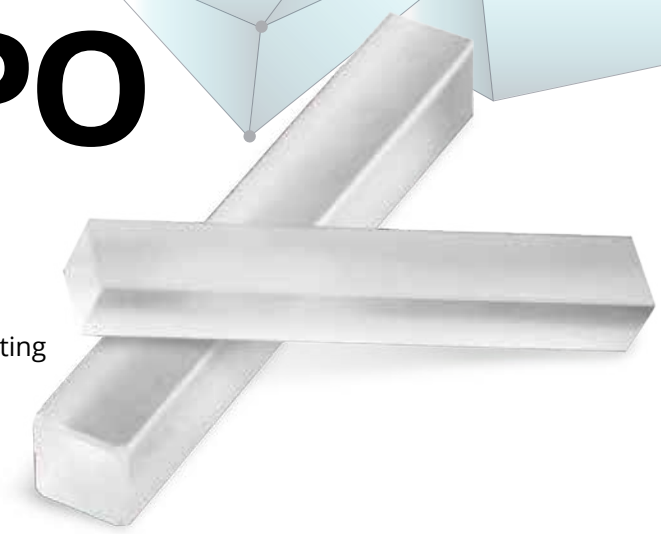
KTP is the most common NLO crystal for SHG of YAG lasers

- SHG coefficient is approximately three times higher than KDP
- High Laser damage threshold
- Excellent thermal stability
- Large aperture up to 50x50 mm

KTP material is widely recognized for efficient OPO, SHG & Quantum applications.

KTP OPO
Crystals

KTP OPO (Optical Parametric Oscillator) is the most efficient material for converting 1064 nm wavelength laser to 1572 nm ("eye safe") and other wavelengths.



Advantages

- Aperture – up to 30x30 mm^2
- Length – up to 40 mm
- Available in Regular, Monolithic (Single and Double pass with Mirror coating), Plano-Plano and Confocal OPO configurations
- NCPM for eye-safe signal (1572 nm) No Walk-Off
- Efficiency of Monolithic OPO is 20-30% higher than a typical OPO
- Divergence of Laser with Confocal OPO is lower than Plano-Plano OPO
- Walk-Off Compensating design (WOC) available at 2.1µm

Common Applications

- Laser Range Finders (LRF)
- Laser designators
- LIDAR, space and other civil applications.

HGTR KTP
High Gray Track Resistance Crystals

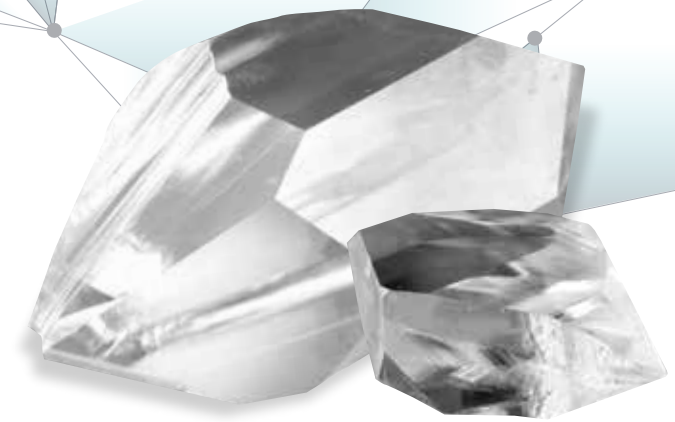
Raicol was the first to develop High Gray Track Resistance flux grown KTP crystals that enables higher average power density in SHG of 1000-1400 nm.
Gray tracks are produced when a crystal is subjected to high power, high repetition rate laser pulses or CW laser irradiation. The gray tracks occur due to induced color centers in the KTP crystal that have broad optical absorption in the visible and near infrared wavelengths, especially at 532 nm. The process of the gray track formation is cumulative and leads to deterioration of harmonic conversion.

Advantages

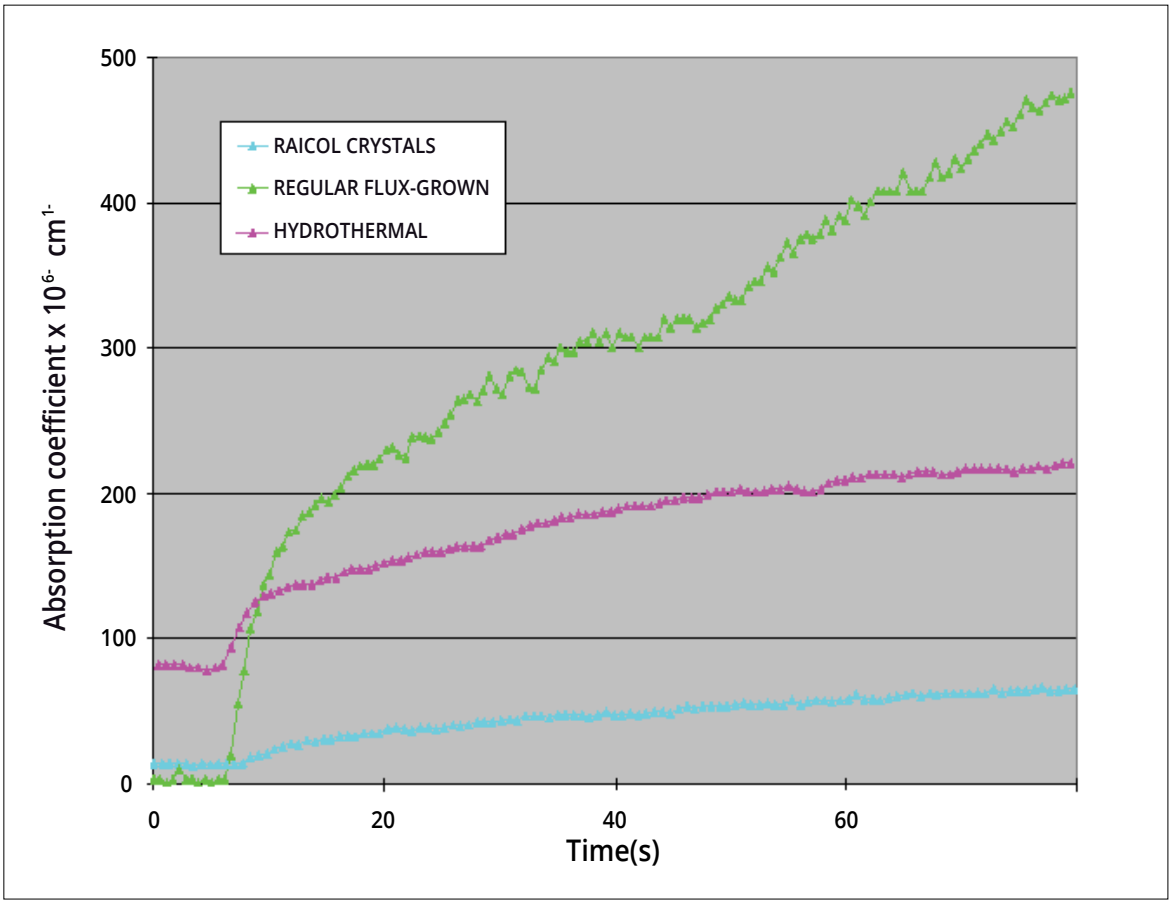
- Average output power density at 532 nm up to 5 kW/ cm² according to laser regime
- Nonlinear coefficient 4 times higher than LBO
- Low absorption at visible and near infrared wavelengths
- Broad temperature bandwidth
- Non-hygroscopic material
- Small walk-off and wide angular bandwidth

Common Applications

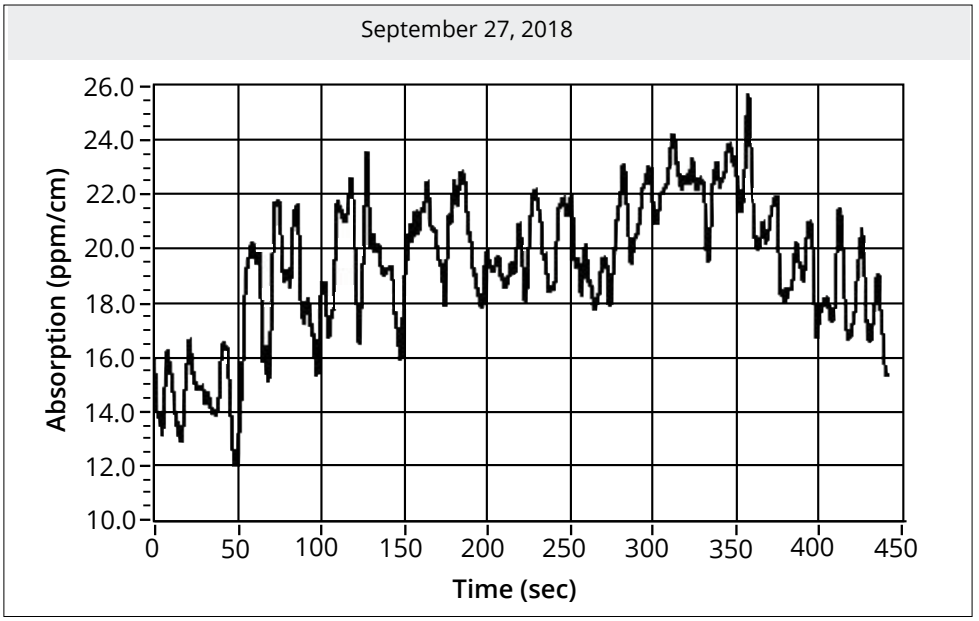
Medium power green lasers for medical, industrial, scientific and other applications



Comparison of Gray - Tracking Effect in KTP Crystals @1064nm absorption growth under 10 KW/cm² of green light @532

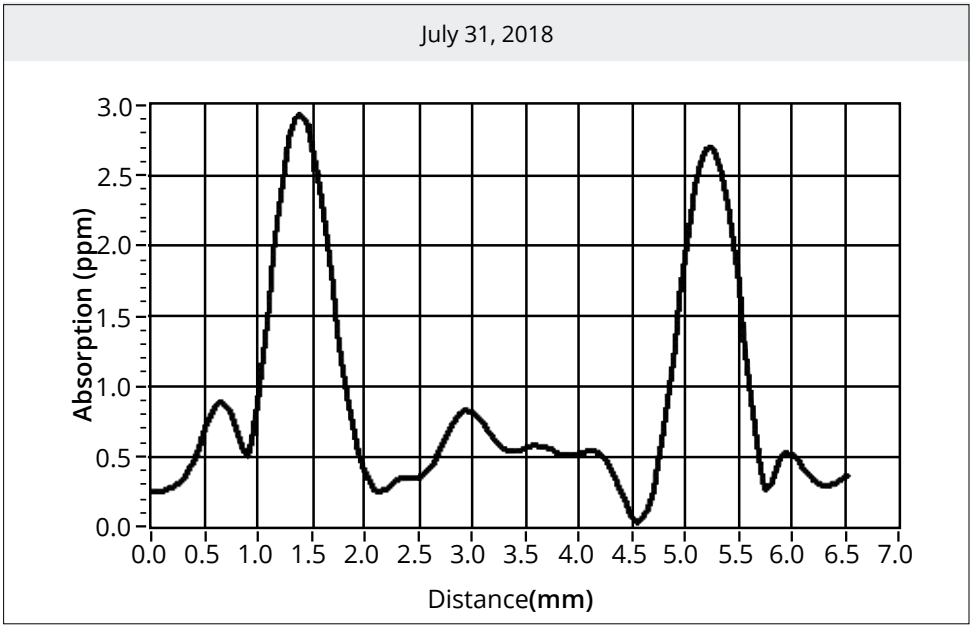


HGTR KTP GRIIRA Graph



Time dependent dynamics of absorption in the crystal bulk @532 nm under self-radiation of 532nm. This parameter indicates the effectiveness and gray tracking resistance of the crystals. This is correlated to the crystal's lifetime - the lower the value, the longer the expected lifetime.

HGTR KTP Coating Absorption Graph @1064



KTP Types

Specifications Comparison:

	KTP (SHG, OPO)	HGTR
Max aperture (mm^2)	40x40	5x5
Max length (mm)	40mm	15mm
Bulk Absorption (ppm/cm)	<100 ppm/cm @ 1064 nm; <1000 ppm/cm @ 532 nm	<50 ppm/cm @ 1064 nm; <150 ppm/cm @ 532 nm
Gray Tracking (due to GRIIRA 600 sec ppm/cm*)	2000	150
Laser-Induced Damage Threshold (MW/cm^2) (10ns pulse, 10Hz)	600	600
Average Power Density (W/cm^2)	300 W/cm^2 @1064nm 20 W/cm^2 @532nm	4000 W/cm^2 @1064nm 2500 W/cm^2 @532nm
Typical Resistivity (Ohm*cm)	10^7	10^{11}
Flatness	λ/10 @ 633 nm	λ/10 @ 633 nm
Wavefront Distortion	λ/4 @ 633 nm	λ/4 @ 633 nm
Perpendicularity (arc min)	< 10 arc min	< 10 arc min
Surface Quality (Scratch/dig)	10/5	10/5
Parallelism (arcsec)	Better than 30 arcsec	Better than 30 arcsec
Coating	DBAR OPO - Monolithic	DBAR
Orientation	<20 arc min	<20 arc min

*Curve dynamics depends on IR absorption in the crystal bulk under self-radiation of 532nm.
This parameter indicates the gray-tracking resistance of the crystal.
This is correlated to the crystal's lifetime- the smaller the value the longer the expected lifetime.

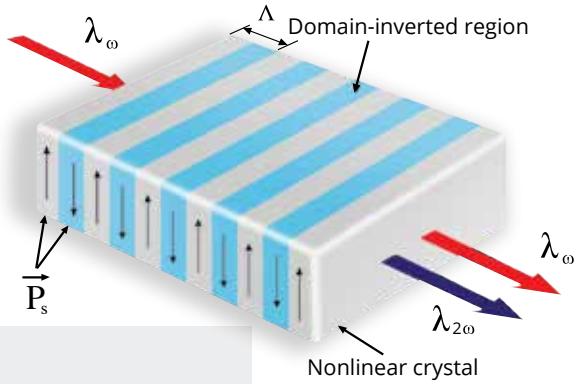
PPKTP

Periodically Poled KTP

Periodically Poled KTP (PPKTP) is a unique type of nonlinear material that is based on quasi-phase matching (QPM). It can be tailor-made for all nonlinear applications within the transparency range of KTP, without the phase matching limitations of phase matching used in regular KTP interactions. Its effective nonlinear coefficient is about three times larger than that of bulk KTP.
Raicol has more than 20 years experience in developing and manufacturing PPKTP for various applications. The company pioneered an original manufacturing process that has allowed reliable supply of PPKTP over the years. Raicol offers PPKTP in large production quantities, as well as small quantities for R&D activities.

Advantages

- Highest nonlinear coefficient
- Free of Walk-Off
- Large quantities for OEM mass-production as well as small quantities for R&D
- Broad phase-matching range
- Type 0 or type II interaction



Common Applications

SHG, SFG, DFG, and OPO applications from visible up to mid IR, SPDC for Quantum applications

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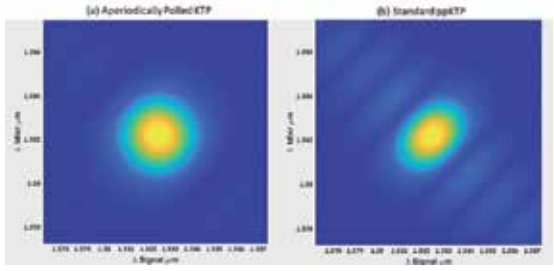
APKTP

APKTP is a special type of PPKTP crystal which maximizes spectral purity at telecom wavelengths. It is a type-2 crystal, suitable for pumping with Ti-Sapphire lasers (775-795nm), based on a unique aperiodic polling design for internal filtering of the joint-spectrum.



The leading crystal for quantum applications

For more than 20 years, Raicol has been deepening its unique know-how in the manufacture of quasi phase-matched ppKTP and aperiodic poled KTP (apKTP)crystals. By controlling the complete manufacture process, from the growth of the crystal to its periodic poling, Raicol fine-tuned its products to accommodate the needs of the quantum industry. In recent years, Raicol Quantum has worked alongside academic partners to optimize the ppKTP crystals as sources of entangled photon pairs and heralded single-photons forquantum-key distribution, computing, sensing, imaging and more.

Raicol's ppKTP and apKTP crystals are prominent SPDC sources for:

- Entanglement with high spectral purity
- Polarization entanglement
- Squeezed light
- Broadband/narrowband type-0 and type-2 down conversion

Typical Specifications for PPKTP

Transparency Range:	350-4000 nm
Length:	Up to 30 mm
Standard Aperture*:	1×2 up to 2X10 mm^2
Operating Temperature	Near room temperature / Per request
Coating Options:	Extra/Intra cavity, AR/AR, AR/HR, HR/HR, DBAR, TBAR, IBS
Laser Induced Damage Threshold	600 MW/cm^2 @1064 nm, for 10 ns pulses

*Custom apertures are available upon request

BBO
Crystals and EO Cells

Beta-barium borate (BBO) is a versatile nonlinear crystal ideally suited for nonlinear laser interactions.
BBO crystals combine very wide transparency, high nonlinear coupling, high damage threshold and good chemical and mechanical properties. BBO phase matches over a wide range, yielding SHG, SFD and OPO from 190 to 1780 nm.

Advantages

- Very wide transparency range up to the deep UV
- High damage threshold
- High nonlinear coefficient

  High optical homogeneity
- Wide temperature-bandwidth

Common Applications

- Second, third, fourth, and fifth harmonic generation of ND: YAG lasers
- Second, third, and fourth harmonic generation of Ti: Sapphire and Alexandrite lasers
- SHG of Argon, Cu Vapor and Ruby lasers
- OPO of UV and visible wavelengths
- Electro optical cells

Typical Specifications for BBO

Aperture	Up to 25x25 mm^2
Length	Up to 30 mm
Flatness	Up to λ/10 @633nm
Perpendicularity	Up to 5 arc min.
Parallelism	Up to 5 arc sec.
Scratch/Dig	10/5
AR Coatings	AR/AR, DBAR dual band R < 0.2 %
Absorption Coefficient	< 50ppm cm^{-1} @1064nm < 100ppm cm^{-1} @532nm
Wave Front Distortion Control	λ/8 @633nm
Guaranteed Laser Induced Threshold	5 GW/cm^2 @1064 nm 1 GW/cm^2 @532 nm For 10 ns pulses

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