CASTECH®

福晶科技

CRYSTAL CATALOG

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GWU-Lasertechnik

GWU

福建福晶科技股份有限公司

CASTECH INC.

Potassium Titanyl Phosphate($KTiOPO_4$, KTP)

Introduction

Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP) is widely used in both commercial and military lasers including laboratory and medical systems, range-finders, lidar, optical communication and industrial systems.

CASTECH's KTP is featured by

- Large nonlinear optical coefficient
- Wide angular bandwidth and small walk-off angle
- Broad temperature and spectral bandwidth
- High electro-optic coefficient and low dielectric constant
- Large figure of merit
- Nonhydroscopic, chemically and mechanically stable

CASTECH offers

- Strict quality control
- Large crystal size up to 20x20x40mm^3 and maximum length of 60mm;
- Quick delivery (2 weeks for polished only, 3 weeks for coated)
- Unbeatable price and quantity discount
- Technical support
- AR-coating, mounting and re-polishing service

Table 1. Chemical and Structural Properties

Crystal Structure	Orthorhombic, space group $Pna2_1$,point group mm2
Lattice Parameter	a=6.404Å, b=10.616Å, c=12.814Å, Z=8
Melting Point	About 1172°C
Mohs Hardness	5
Density	3.01 g/cm^3
Thermal Conductivity	13W/m/K
Thermal Expansion Coefficient	α_x=11x10^{-6}/^{0}C, α_y=9x10^{-6}/^{0}C, α_z=0.6x10^{-6}/^{0}C

Table 2. Optical and Nonlinear Optical Properties

Transparency Range	350-4500nm
SHG Phase Matchable Range	497-1800nm (Type II)
Therm-optic Coefficients ($/^0C$)	$dn_x/dT=1.1X10^{-5}$ $dn_y/dT=1.3X10^{-5}$ $dn_z/dT=1.6X10^{-5}$
Absorption Coefficients	<0.1%/cm at 1064nm <1%/cm at 532nm
For Type II SHG of a Nd:YAG laser at 1064nm	Temperature Acceptance: 24°C·cm Spectral Acceptance: 0.56nm·cm Angular Acceptance: 14.2mrad·cm (φ); 55.3mrad·cm(θ) Walk-off Angle: 0.55°
NLO Coefficients	$d_{eff}(II)\approx (d_{24} - d_{15})\sin2\phi\sin2\theta - (d_{15}\sin^2\phi + d_{24}\cos^2\phi)\sin\theta$
Non-vanished NLO Susceptibilities	d_{31}=6.5 pm/V d_{24}=7.6 pm/V d_{32}=5 pm/V d_{15}=6.1 pm/V d_{33}=13.7 pm/V
Sellmeier Equations (λin μm)	$n_x^2=3.0065+0.03901/(\lambda^2-0.04251)-0.01327\lambda^2$ $n_y^2=3.0333+0.04154/(\lambda^2-0.04547)-0.01408\lambda^2$ $n_z^2=3.0065+0.05694/(\lambda^2-0.05658)-0.01682\lambda^2$
Electro-optic Coefficients:	Low frequency (pm/V) High frequency (pm/V)
r_{13}	9.5 8.8
r_{23}	15.7 13.8
r_{33}	36.3 35.0
r_{51}	7.3 6.9
r_{42}	9.3 8.8
Dielectric Constant:	ε_{eff}=13

Applications for SHG and SFG of Nd: lasers

KTP is the most commonly used material for frequency doubling of Nd:YAG and other Nd-doped lasers, particularly when the power density is at a low or medium level. To date, extra- and intra-cavity frequency doubled Nd:lasers using KTP have become a preferred pumping source for visible dye lasers and tunable Ti:Sapphire lasers as well as their amplifiers. They are also useful green sources for many research and industry applications.

- More than 80% conversion efficiency and 700mJ green laser were obtained with a 900mJ injection-seeded Q-switch Nd:YAG lasers by using extra-cavity KTP.
- 8W green laser was generated from a 15W LD pumped $Nd:YVO_4$ with intra-cavity KTP.
- 200mW green outputs are generated from 1W LD pumped $Nd:YVO_4$ lasers by using CASTECH's 2x2x5mm^3 KTP and 3x3x1mm^3 $Nd:YVO_4$.
- 2-5mw green outputs are generated from 180mw LD pumped $Nd:YVO_4$ and KTP glued crystals. For more details, please refer to P67.

KTP is also being used for intracavity mixing of 0.81μm diode and 1.064μm Nd:YAG laser to generate blue light and intracavity SHG of Nd:YAG or Nd:YAP lasers at 1.3μm to produce red light.

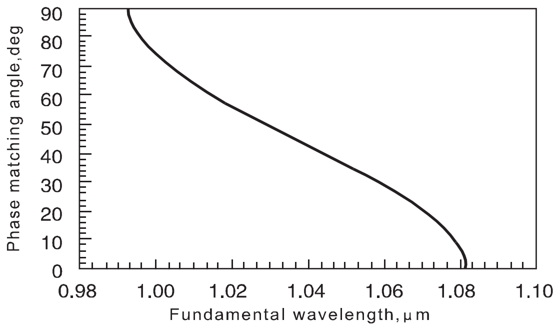


Fig. 1 Type II KTP SHG in XY Plane

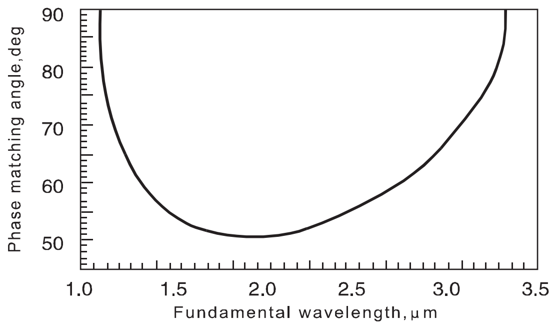


Fig. 2 Type II KTP SHG in XZ Plane

Applications for OPG, OPA and OPO

As an efficient OPO crystal pumped by a Nd:laser and its second harmonics, KTP plays an important role for parametric sources for tunable outputs from visible (600nm) to mid-IR (4500nm), as shown in Fig. 3 and Fig. 4.

Generally, KTP's OPOs provide stable and continuous pulse outputs (signal and idler) in fs, with 10^8 Hz repetition rate and a miniwatt average power level. A KTP's OPO that are pumped by a 1064nm Nd:YAG laser has generated as high as above 66% efficiency for degenerately converting to 2120nm.

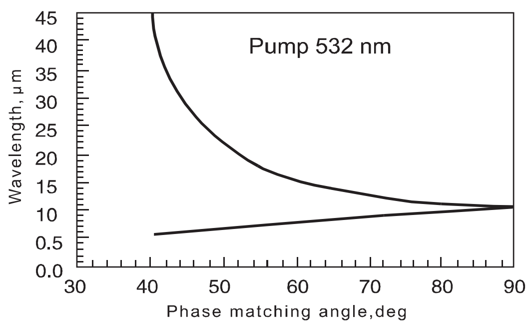


Fig. 3 OPO pumped at 532 in X-Z plane

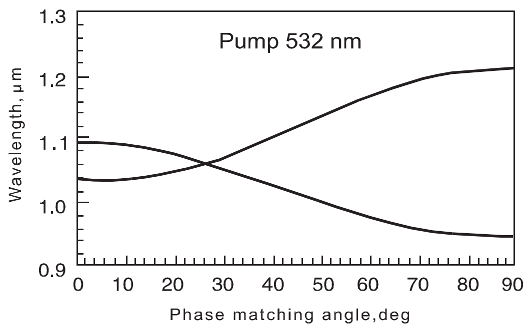


Fig. 4 OPO pumped at 532 in X-Y plane

The novel developed application is the non-critical phase matched (NCPM) KTP's OPO/OPA. As shown in Fig.5, for pumping wavelength range from 0.7μm to 1μm, the output can cover from 1.04μm to 1.45μm (signal) and from 2.15μm to 3.2μm (idler). More than 45% conversion efficiency was obtained with narrow output bandwidth and good beam quality.

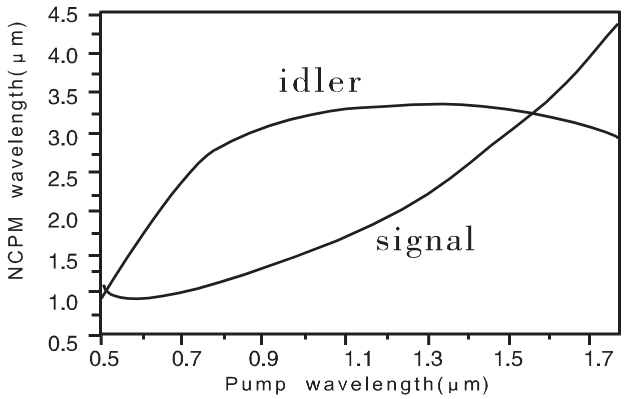


Fig. 5 Type II NCPM OPO

Applications for E-O Devices

In addition to unique NLO features, KTP also has promising E-O and dielectric properties that are comparable to $LiNbO_3$. These advantaged properties make KTP extremely useful to various E-O devices. Table 1 is a comparison of KTP with other E-O modulator materials commonly used:

Table 1. Electro-Optic Modulator Materials

Material			Phase			Amplitude		
	ε	N	R(pm/V)	k(10^{-6}/°C)	$N^7r^2/\varepsilon(pm/V)^2$	r(pm/V)	k(10^{-6}/°C)	$n^7r^2/\varepsilon(pm/V)^2$
KTP	15.42	1.80	35.0	31	6130	27.0	11.7	3650
$LiNbO_3$	27.9	2.20	8.8	82	7410	20.1	42	3500
KD^*P	48.0	1.47	24.0	9	178	24.0	8	178
$LiIO_3$	5.9	1.74	6.4	24	335	1.2	15	124

From Table 1, clearly, KTP is expected to replace $LiNbO_3$ crystal in the considerable volume application of E-O modulators, when other merits of KTP are combined into account, such as high damage threshold, wide optical bandwidth (>15GHZ), thermal and mechanical stability, and low loss, etc.

Applications for Optical Waveguides

Based on the ion-exchange process on KTP substrate, low loss optical waveguides developed for KTP have created novel applications in integrated optics. Table 2 gives a comparison of KTP with other optical waveguide materials. Recently, a type II SHG conversion efficiency of 20%/W/cm^2 was achieved by the balanced phase matching, in which the phase mismatch from one section was balanced against a phase mismatch in the opposite sign from the second. Furthermore, segmented KTP waveguides have been applied to the type I quasi-phase-matchable SHG of a tunable Ti:Sapphire laser in the range of 760-960mm, and directly doubled diode lasers for the 400-430nm outputs.

Table 2. Electro-Optic Waveguide Materials

Materials	r (pm/V)	n	$\varepsilon_{eff}\,(\varepsilon_{11}\varepsilon_{33})^{1/2}$	n^3r/ε_{eff}(pm/V)
KTP	35	1.86	13	17.3
$LiNbO_3$	29	2.20	37	8.3
$KNbO_3$	25	2.17	30	9.2
BNN	56	2.22	86	7.1
BN	56-1340	2.22	119-3400	5.1-0.14
GaAs	1.2	3.6	14	4.0
$BaTiO_3$	28	2.36	373	1.0

AR-coatings

CASTECH provides the following AR-coatings:

- Dual Band AR-coating (DBAR) of KTP for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm);
  high damage threshold (>300MW/cm2 at both wavelengths);
  long durability.

- Broad Band AR-coating (BBAR) of KTP for OPO applications.
- High reflectivity coating: HR1064nm&HT532nm, R>99.8%@1064nm, T>90%@532nm.
- Other coatings are available upon request.

CASTECH's Warranty on KTP Specifications

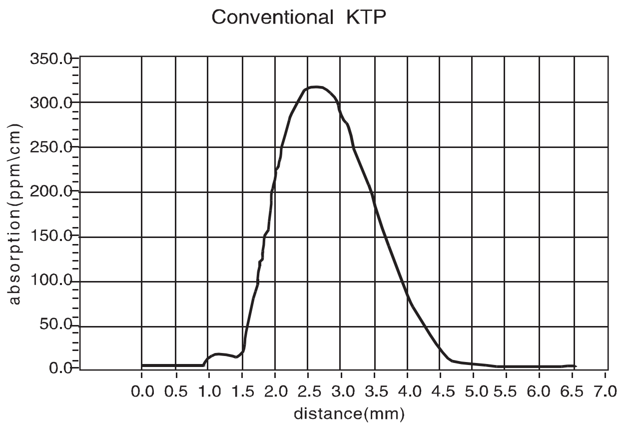
- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer: ≤0.2mm x 45°
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/ 5 to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: ≤0.25°
- Damage threshold[GW/cm^2]: >0.5 for 1064nm, TEM00, 10ns, 10HZ (AR-coated)
  >0.3 for 532nm, TEM00, 10ns, 10HZ (AR-coated)
- Quality Warranty Period: one year under proper use.

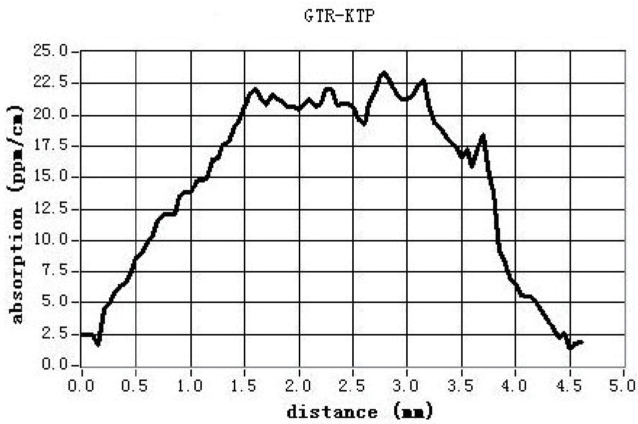
Gray-track Resistance KTP($KTiOPO_4$, GTR-KTP)

Introduction

Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP) is an excellent NLO crystal, widely used in both commercial and military lasers. However conventional KTP suffer a significant drawbacks. The gray track phenomena in conventional KTP limit its application in high repetition and high power laser system. The occurrence of gray-track can be measured by an increase of bulk absorption by a strong CW 532nm green laser within several minutes. This measurement can be performed with Photo-thermal Common-path interferometer.

1. Longitudinal Test (Before Gray Tracking Test):

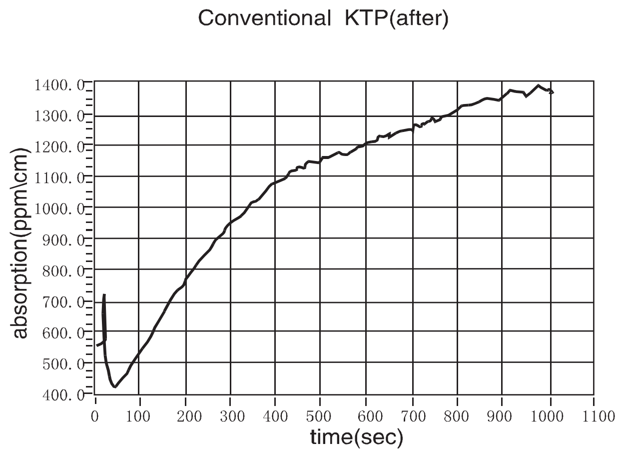


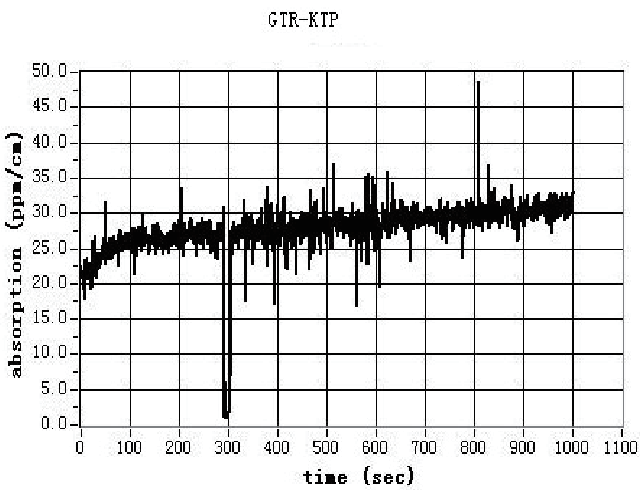


It appears that the absorption of GTR-KTP at 1064nm is only 1/10 of conventional KTP.

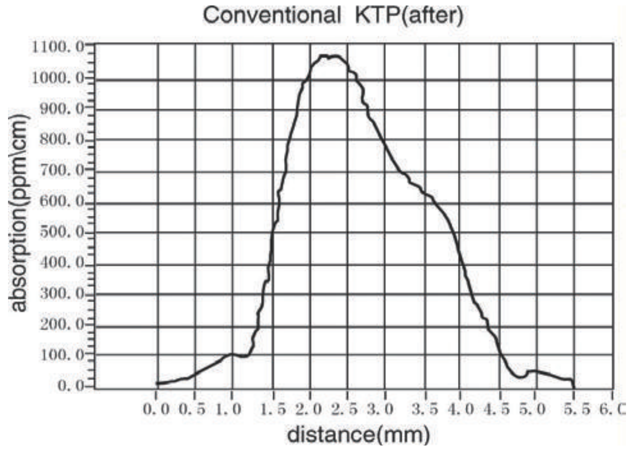
2. Gray Tracking Test:

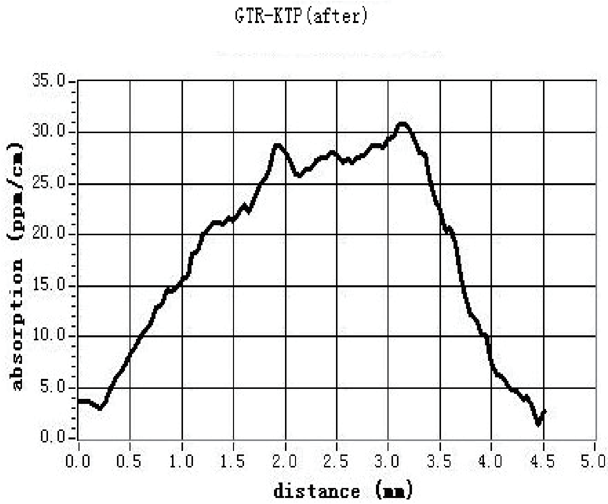
When a green laser beam(400mW, beam diameter 0.07mm, power density 10KW/cm^2) goes through the crystal, it causes an increase in the IR absorption of the crystal. This phenomenon is correlated with “gray tracking effect”. The following graphs show the different absorption levels at 1064nm between CASTECH’s GTR KTP and the conventional KTP.



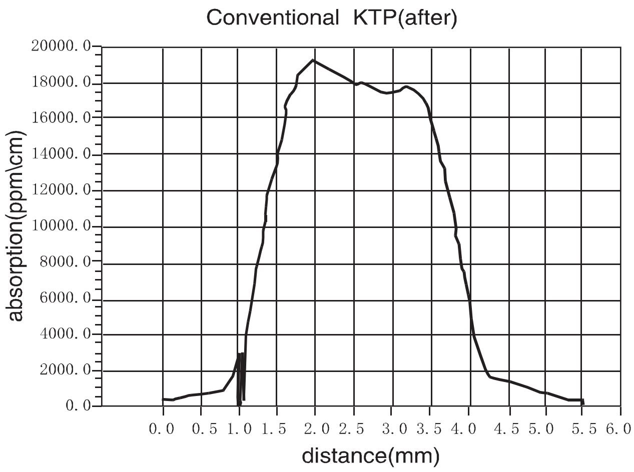


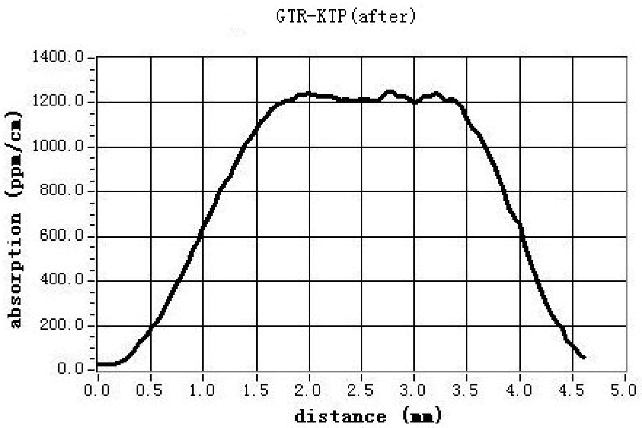
3. Transverse scan after gray tracking test (at 1064 nm)





4. Transverse scan after gray tracking test (at 532 nm) :

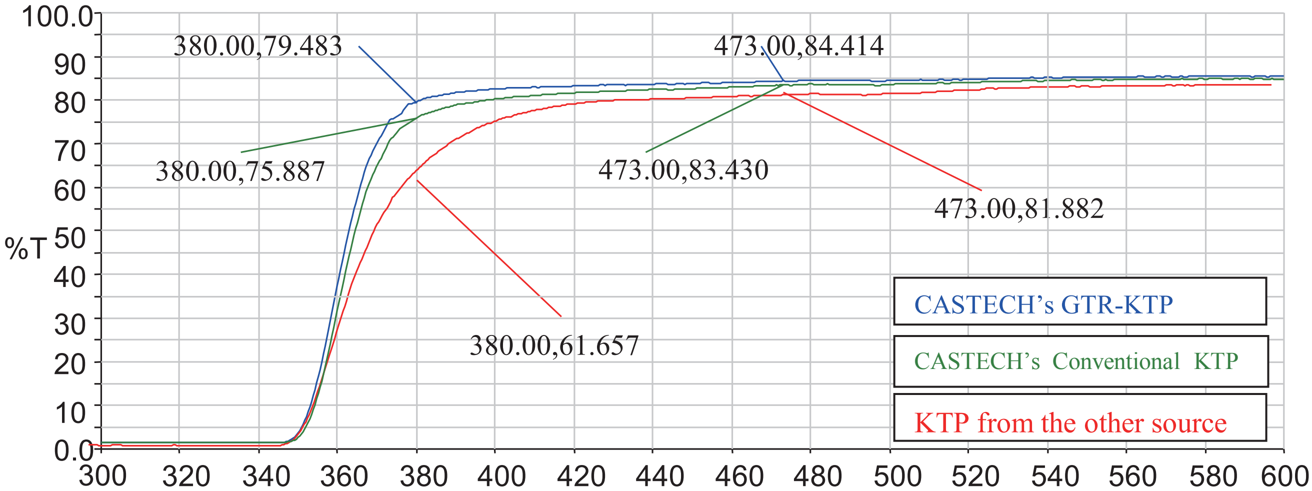




5. Damage threshold testing:

After testing a group of GTR-KTP and the conventional KTP crystals (polished only) with laser condition of 10ns, 1 HZ, we found that CASTECH's GTR-KTP has laser damage threshold around 1.8GW/cm^2 at 1064nm, which is much higher than the conventional KTP(450MW/cm^2 in the same condition).

6. Transmission curve in the visible and UV region:



Apparently CASTECH's GTR-KTP has lower absorption than the conventional KTP in the range of 350-550nm.

We can conclude that CASTECH's GTR-KTP is expected to have a higher gray track resistance than the regular flux grown KTP crystals.

CASTECH provides the following AR-coatings

- IBS, IAD or E-beam coating methods are available upon request.
- Dual Band AR-coating (DBAR) of GTR-KTP for SHG of 1064nm.
  low reflectance (R<0.2% at 1064nm and R<0.5% at 532nm);
  high damage threshold (>1.2GW/cm^2 at 1064nm, >300MW/cm^2 at 532nm, at 10ns, 2.5HZ) long durability.
- Broad Band AR-coating (BBAR) of GTR-KTP for OPO applications.
- High reflectivity coating: HR1064nm&HT532nm, R>99.8%@1064nm, T>95%@532nm.
- Other coatings are available upon request.

CASTECH offers GTR-KTP with

- Strict quality control
- Large crystal size up to 7x7x20mm^3
- Quick delivery(2 weeks for polished only, 3 weeks for coated)
- Unbeatable price and quantity discount
- Technical support
- AR, HR-coating, mounting and re-polishing service

CASTECH's Warranty on GTR-KTP Specifications

- Dimension tolerance: (W±0.1mm)x(H±0.1mm)x(L+0.5/-0.1mm) (L≥2.5mm)
  (W±0.1mm)x(H±0.1mm)x(L+0.1/-0.1mm) (L<2.5mm)
- Clear aperture: central 90% of the diameter
- No visible scattering paths or centers when inspected by a 50mW green laser
- Flatness: less than λ/8 @ 633nm
- Transmitting wavefront distortion: less than λ/8 @ 633nm
- Chamfer: ≤0.2mmx45^0
- Chip: ≤0.1mm
- Scratch/Dig code: better than 10/5(polished only) to MIL-PRF-13830B
  better than 20/10(AR-coated) to MIL-PRF-13830B
  better than 40/20(HR-coated) to MIL-PRF-13830B
- Parallelism: better than 20 arc seconds
- Perpendicularity: ≤5 arc minutes
- Angle tolerance: ≤0.25°

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