Potassium Titanyl Phosphate ($KTiOPO_4$ or KTP)

Advantages

- Large nonlinear optical (NLO) coefficients
- Wide angular bandwidth and small walk-off angle
- Broad temperature and spectral bandwidth
- High electro-optic (E-O) coefficient and low dielectric constant
- Large figure of merit for an optical waveguide
- Modulator
- Nonhygroscopic, good chemical and mechanical properties

Applications

- Frequency doubling (SHG) of Nd-doped lasers for green/red output.
- Frequency mixing (SFM) of Nd laser and diode laser for blue output.
- Parametric sources (OPG, OPA and OPO) for 0.6 µm – 4.5 µm tunable output.
- E-O modulators, optical switches, directional couplers.
- Optical waveguides for integrated NLO and E-O devices.

LASER COMPONENTS provides:

- Standard size of KTP crystal for DPSS application;
- Strict quality control;
- Unbeatable price and special OEM discount;
- Free technical support;
- AR-coating, mounting and re-polishing service;
- Mass production to support industrial and commercial applications;
- Precision oven & temperature controller for heating KTP.

United Kingdom
Laser Components (UK) Ltd.
Tel: +44 1245 491 499
Fax: +44 1245 491 801
info@lasercomponents.co.uk
www.lasercomponents.co.uk

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Basic Properties

1. Structural and Physical Properties

Crystal sructure	orthorhombic, point group mm^2
Cell parameters	a = 6.404 Å, b = 10.616 Å, c = 12.814 Å Z = 8
Melting point	1172 °C incongruent
Curie point	936 °C
Mohs hardness	≈5.0
Density	3.01 g/cm^3
Linear absorption coefficients	α<0.001 cm^{-1}@λ=1064 nm or 532 nm
Hygroscopic susceptibility	no
Relative dielectric constant	ε_{eff}=13
Specific heat	0.1643 cal/g.°C
Electrical conductivity	3.5 x 10^{-8} s/cm (c-axis, 22 °C, 1 KHz)
Thermal conductivity	13 W/m/K

2. Linear Optical Properties

Transparency range	350 – 4500 nm, see transparency curv		
Refractive indices Wavelength 1064 nm 532 nm	n_x 1.7377 1.7780	n_y 1.7453 1.7886	n_z 1.8297 1.8887
Therm-optic coefficients	$dn_x/dT=1.1x10^{-5}$/°C $dn_y/dT=1.3x10^{-5}$/°C $dn_z/dT=1.6x10^{-5}$/°C		
Sellmeier equations	$n^2_x=3.0065+0.03901/(\lambda^2-0.04251)-0.01327\lambda^2$ $n^2_y=3.0333+0.04154/(\lambda^2-0.04547)-0.01408\lambda^2$ $n^2_z=3.3134+0.05694/(\lambda^2-0.05658)-0.01682\lambda^2$		

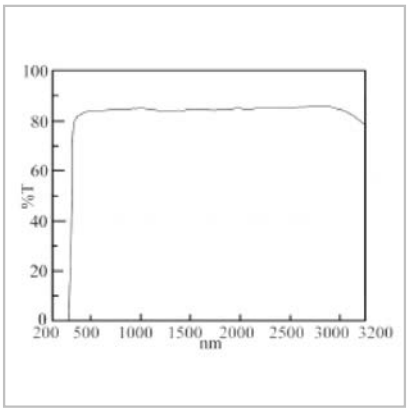

Figure 1:
KTP Transparency Curve

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2. Nonlinear Optical Properties

Phase-matchable output range	492 – 1700 nm	
NLO coefficients	d_{31}=2.54pm/V, d_{32}=4.35pm/V, d_{33}=16.9pm/V d_{24}=3.64pm/V, d_{15}=1.91pm/V at 1064 nm $d_{eff}(II) \approx (d_{24} - d_{15})\sin^2\phi\sin^2\theta - (d_{15}\sin^2\phi + d_{24}\cos^2\phi)\sin\theta$	
Electro-optic coefficients	low frequency (pm/V)	high frequency (pm/V)
$\gamma 13$	9.5	8.8
$\gamma 23$	15.7	13.8
$\gamma 33$	36.3	35.0
$\gamma 51$	7.3	6.9
$\gamma 42$	9.3	8.8

Applications for SHG and SFG of Nd:LASERS

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. The following table lists the major NLO properties of KTP for frequency-doubling of Nd:YAG laser.

PM angle	θ=90°, ϕ=23.5°, where θ & ϕ are polar angles referring to Z and X
Effective SHG coefficient	$d_{eff} \approx 8.3 x d_{36}$(KDP)
Angular acceptance	20 mrad-cm
Temperature acceptance	25 °C-cm
Spectral acceptance	5.6 Å-cm
Walk-off angle	4.5 mrad (0.26°)
Optical damage threshold	>450 MW/cm^2, (@ 1.06 µm, 10 ns, 10 Hz)

To date, extra- and intra-cavity frequency doubled Nd:lasers using KTP have become a preferred green laser source for many R&D, medical, industrial and commercial applications. By using extracavity KTP SHG, over 80% conversion efficiency and 700 mJ green laser were obtained with a 900 mJ injection seeded Q-switched Nd:YAG laser.

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Applied to diode-pumped Nd:laser, KTP is a basic NLO crystal for the construction of compact visible solid state laser systems. Recent advances in intracavity doubled Nd:YVO_4 and Nd:YAG lasers have increased the demand for compact green lasers used in display, construction, optical disk and laser printer. Over 200 mw TEM_{00} green outputs are available from LD pumped Nd:YVO_4 and Nd:YAG lasers and 3 W TEM_{00}, mode-locked green laser was generated by intracavity SHG in a 5.3 W mode-locked diode-laser pumped Nd:YAG laser. Moreover, 2.5 mW green light was obtained from 50 mW LD pumped and intra-cavity doubled Nd:YVO_4 mini-lasers with a 9 mm long cavity.

KTP is also a powerful crystal for SHG and SFG of laser with wavelength from about 1 µm to 3.4 µm. The SHG phase-matching angle and effective SHG coefficients (d_{eff}) of KTP in XY plane (0.9 µm to 1.08 µm) and XZ plane (1.1 µm to 3.3 µm) are showed as the figures. Although KTP cut in YZ plane can be phase-matched for SHG of 1 µm to 3.45 µm, it is seldom used in practices because of the low d_{eff}.

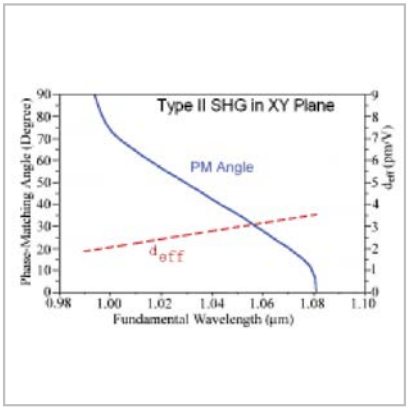

Figure 2:
Type II SHG in XY Plane

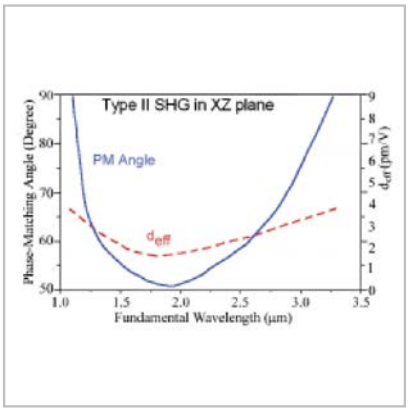

Figure 3:
Type II SHG in XZ Plane

APPLICATIONS FOR OPG, OPA AND OPO

As an efficient OPO crystal pumped by the fundamental and second harmonics of a Nd:YAG or Nd:YLF laser, KTP plays an important role in parametric sources for tunable output from visible (0.6 µm) to mid-IR (4.5 µm). The phase-matching angles and effective NLO coefficient for OPO/OPA pumped at 532 nm and 1064 nm in XZ plane are showed as following figures. NCPM KTP OPO pumped by 1064 nm, the signal output is around eye safe wavelength, applications are found in eye-safe devices. The OPO/OPA in XY and YZ is seldom employed because of their low effective nonlinear coefficients and other limitations. For more information about the design of KTP-OPO, please contact us.

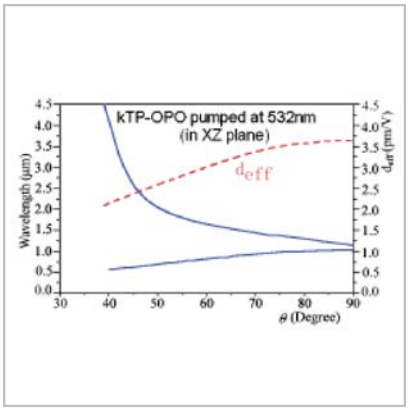

Figure 4:
OPO Pumped at 532 nm

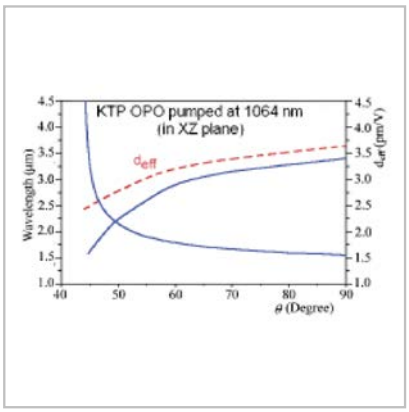

Figure 5:
OPO Pumped at 1064 nm

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KTP's OPO results in stable, continuous outputs of femtosecond pulse of 108 Hz repetition rate and miliwatt average power levels in both signal and idler outputs. KTP's OPO pumped by a 1064 nm Nd:laser has generated above 66% conversion efficiency for degenerate conversion from 1064 to 2120 nm.

The recently developed new application is the noncritical phase-matched (NCPM) KTP OPO/OPA pumped by the tunable lasers such as Ti: Sapphire, Alexandrite and Cr: $LiSrAlF_6$ (see right figure). The NCPM KTP OPO keeps the KTP crystal fixed in X-axis and tunes the pumping wavelength. If a tunable Ti:Sapphire laser is used as a pumping source (0.7 µm to 1 µm), the output can cover the wavelength range from 1.04 µm to 1.45 µm (signal) and from 2.15 µm to 3.2 µm (idler). Due to the favorable NLO properties of NCPM KTP, as high as 45% conversion efficiency was obtained with narrow output bandwidth and good beam quality.

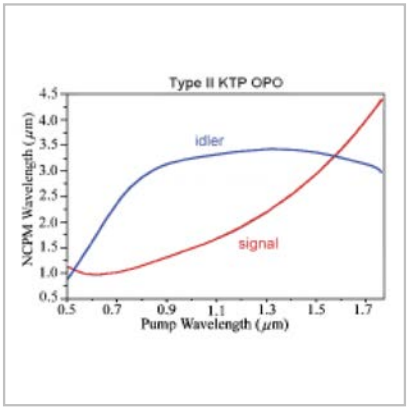

Figure 6

Quasi-Phase-Matched Waveguide

Recently, type II SHG conversion efficiency of 20%/W/cm^2 was achieved by quasi-phase matched waveguide doubler, in which the phase mismatch from one section is balanced against a phase mismatch of the opposite sign from a second section. Furthermore, segmented KTP waveguides have been applied to type I quasi-phase-matchable SHG of 0.76 – 0.96 µm for tunable Ti:Sapphire laser and directly doubled diode laser for 0.43 – 0.40 µm output. Conversion efficiency in excess of 100%/W/cm^2 has been obtained.

Now, we can provide as large as 30x30x1 mm KTP with -Z or both faces polished for waveguide applications. Other size is also available upon request.

Oven for Heating KTP Crystals

Increasing the temperature of KTP crystal can enhance the damage threshold of KTP crystal. Therefore, for high power or high power density SHG of Nd lasers, heating KTP to a certain temperature (e.g., 80 °C) is recommended. We provide precision oven with temperature controller for heating KTP. A full assembly including KTP crystal, oven and temperature controller is also available.

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Our Warranty on KTP Specifications

Transmitting wavefront distortion	less than λ/4 @ 633 nm
Dimension tolerance	(W± {0.1mm) x (H±} 0.1mm) x (L+0.2mm/- 0.1)
Clear aperture:	>90% central area
Flatness	λ/8 @ 633 nm
Surface quality	10/5 scratch/dig
Parallelism	better than 20 arc sec.
Perpendicularity	15 arc min.
Angle tolerance	$\Delta\theta < 0.5°$, $\Delta\phi < 0.5°$
AR coating	dual wave band AR coating at 1064/532 nm for both faces
Residual reflectivity	<0.2% at 1064 nm and <0.5% at 532 nm per surface
Quality warranty period	one year under proper use

Note:

1. LASER COMPONENTS has large quantities of standard size KTP crystals available. The standard size crystals include 2 x 2 x 5 mm, 3 x 3 x 5 mm and 5 x 5 x 5 mm etc. with dual-band AR-coating for frequency-doubling 1064 nm.
2. We provide free crystal samples for long term technical and business cooperation as well as the developments of KTP's new applications. Qualified end-users can also obtain free samples upon request.
3. AR-coatings and High Reflection coatings (HR-coatings) at other wavelengths are available upon request.
4. Technical information and specific designs for KTP crystals are provided by our sales engineers and the scientists in our R&D center.

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