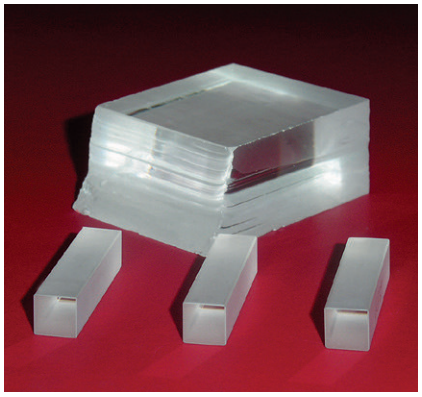
Raman Crystals

KGW / $Ba(NO_3)_2$ – CRYSTALS FOR STIMULATED RAMAN SCATTERING



EKSMA OPTICS offers crystalline materials – **Barium Nitrate – $Ba(NO_3)_2$** and **undoped potassium gadolinium tungstate $KGd(WO_4)_2$** or KGW which have attracted much interest for stimulated Raman scattering (SRS). These materials can be used for frequency conversion in lasers for extending the tuning range. SRS in crystals is compatible with current all-solid-state technology and provides a very simple, compact means of frequency conversion.

$Ba(NO_3)_2$ has a highest Raman gain coefficient. The gain coefficient affects the threshold for Raman laser. However, the thermal lensing is particularly strong in this material. This is indicated by the large value ∂n/∂T and low thermal conductivity. Thermal effects are significantly smaller in KGW. This along with the high damage threshold make the crystal an excellent candidate for power scaling.

Comparing $Ba(NO_3)_2$ and KGW for Raman application $Ba(NO_3)_2$ is more optimal in case of ns and longer pulses, KGW – in case of shorter pulses.

$Ba(NO_3)_2$ PHYSICAL AND OPTICAL PROPERTIES

Crystal symmetry	cubic, $P2_13$
Transmission range	0.35 – 1.8 μm
Density	3.25 g/cm^3
Hardness Mohs	2.5 – 3
Refractive indices @ 1064 nm	n = 1.555
Raman shift	1048 cm^{-1}
Raman gain, pump 1064 nm	11 cm/GW
Thermal conductivity, W/mK	1.17
∂n/∂T	-20×10^{-6} K^{-1}
Optical Damage Threshold	~ 0.4 GW/cm^2

KGW PHYSICAL AND OPTICAL PROPERTIES

Crystal symmetry	monoclinic, C2/c
Transmission range	0.35–5.5 μm
Density	7.27 g/cm^3
Hardness Mohs	4-5
Refractive indices @ 1064 nm	n_g = 2.061; n_m = 2.010; n_p = 1.982
Raman shift	901 cm^{-1} (p[mm]p) 768 cm^{-1} (p[gg]p)
Raman gain, pump 1064 nm	3.3 cm/GW (901 cm^{-1}) 4.4 cm/GW (768 cm^{-1})
Thermal conductivity, W/mK	K_a=2.6; K_b=3.8; K_c=3.4
∂n/∂T	0.4 × 10^{-6} K^{-1}
Optical Damage Threshold	> 10 GW/cm^2

RAMAN WAVELENGTHS
in KGW (oscillation coefficient 901.5 cm^{-1}) and $Ba(NO_3)_2$ (oscillation coefficient 1048.6 cm^{-1}) crystals

Stokes	KGW pumped @ 532 nm	KGW pumped @ 1064 nm	$Ba(NO_3)_2$ pumped @ 532 nm	$Ba(NO_3)_2$ pumped @ 1064 nm	Typical efficiency, %
1 Stoke	558	1177	563	1197	35–70
2 Stoke	588	1316	598	1369	20–40
3 Stoke	621	1494	638	1599	10–15
4 Stoke	658	1726	684	1924	<10
1 Antistoke	507	970	503	957	10–30

STANDARD SPECIFICATIONS

	$Ba(NO_3)_2$	KGW
Surface Quality, scratch & dig (MIL-PRF-13830B)	40-20	10-5
Flatness @ 633 nm	λ/4	λ/8
Maximal element dimensions, mm	10×10×100	10×10×80

STANDARD KGW CRYSTALS. Updoped, b-cut

Dimensions, mm	Coating	Catalogue number	Price, EUR
7 × 7 × 30	Uncoated	KGW-701	600
5 × 7.5 × 30	BBAR/BBAR @ 400 – 700 nm	KGW-702	785

Barium & Strontium tungstate-molybdate – CRYSTALS FOR RAMAN SHIFT

- $Ba(MoO_4)_X(WO_4)_{1-X}$, 0<x<0.01
- $Sr(MoO_4)_X(WO_4)_{1-X}$, 0<x<0.01
- $Sr(MoO_4)_X(WO_4)_{1-X}$, 0.99<x<1

New Barium and Strontium tungstate-molybdate single crystals feature higher Raman gain as compared to KGW or $CaCO_3$ and relatively higher thermal conductivity as compared to a $Ba(NO_2)_3$.

Barium and Strontium tungstate-molybdate single crystals are grown and provided with cut along a-direction. Active elements do not require precise positioning since stimulated Raman scattering (SRS) threshold slightly depends on the crystal orientation relative to pump polarization (within a few percent) and minimum threshold is reached at E||c. In this case, the polarization of the pump and stokes pulses are parallel to the optical axis (c-axis).

The crystals are water-insoluble and durable. Available sizes and shapes of active elements are rectangular up to 10 × 10 × 100 mm or with cylindrical cross-section up to Ø10 × 100 mm.

APPLICATIONS

- Raman converters – new crystals extend the capabilities of the Raman devices in addition to commercially available $Ba(NO_2)_3$, $CaCO_3$, KGW crystals, since new crystals have different values of the Stokes shift and allow to obtain a laser radiation at the other wavelengths
- Raman lasers including self-Raman generation
- Laser pulse compressors based on stimulated Raman scattering effect

RAMAN WAVELENGTHS GENERATION IN BARIUM TUNGSTATE, STRONTIUM TUNGSTATE AND STRONTIUM MOLYBDATE SINGLE CRYSTALS

Crystal	Barium tungstate		Strontium tungstate		Strontium molybdate	
Chemical formula	$Ba(MoO_4)_X(WO_4)_{1-X}$ 0 < x < 0.01		$Sr(MoO_4)_X(WO_4)_{1-X}$ 0 < x < 0.01		$Sr(MoO_4)_X(WO_4)_{1-X}$ 0.99 < x < 1	
Oscillation coeficient	925 cm^{-1}		921.5 cm^{-1}		888 cm^{-1}	
Pump	1064 nm	532 nm	1064 nm	532 nm	1064 nm	532 nm
1 Stoke	1180	560	1180	559	1175	558
2 Stoke	1325	590	1324	590	1312	588
3 Stoke	1510	624	1507	624	1485	620
4 Stoke	1755	662	1751	662	1710	656
1 Antistoke	969	507	969	507	972	508

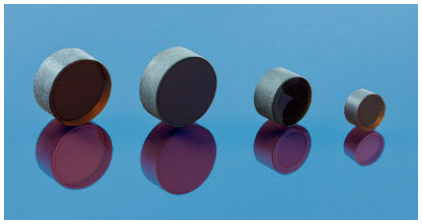
PHYSICAL AND OPTICAL PROPERTIES

Crystal	Barium tungstate	Strontium tungstate	Strontium molybdate
Chemical formula	$Ba(MoO_4)_X(WO_4)_{1-X}$ 0 < x < 0.01	$Sr(MoO_4)_X(WO_4)_{1-X}$ 0 < x < 0.01	$Sr(MoO_4)_X(WO_4)_{1-X}$ 0.99 < x < 1
Crystal structure	Tetragonal, space group $I4_1/a$	Tetragonal, space group $I4_1/a$	Tetragonal, space group $I4_1/a$
Density	6.35 g/cm^3	6.26 g/cm^3	4.65 g/cm^3
Thermal conductivity	2.3 W/m·K	3 W/m·K	4 W/m·K
Transparency range	0.45 – 5.4 µm	0.25 – 5.4 µm	0.25 – 5.4 µm
Refractive index	n_o =1.806, n_e = 1.804 at 1064 nm n_o =1.848, n_e = 1.846 at 532 nm	n_o =1.84, n_e = 1.85 at 1064 nm n_o =1.87, n_e = 1.88 at 532 nm	n_o =1.878, n_e = 1.88 at 1064 nm n_o =1.919, n_e = 1.924 at 532 nm
Stokes shift	925 cm^{-1}	921.5 cm^{-1}	888 cm^{-1}
Steady-state Raman gain at 1064 nm	8.5 cm/GW	5 cm/GW	5.5 cm/GW
Can be supplied Nd doped: Nd^{3+} concentration in the crystal	0 – 0.15 at. % (on Ba site)	0 – 1.5 at. % (on Sr site)	0 – 1.5 at. % (on Sr site)
Surface optical damage threshold (1064 nm, 4.2 ns)	2 GW/cm^2	1.9 GW/cm^2	0.8 GW/cm^2
Mohs hardness	4	4	4

$BaWO_4$ CRYSTALS FOR RAMAN GENERATION, POLISHED, A-CUT

Dimensions, mm	Coating	Catalogue number	Price, EUR
5 × 5 × 20	Uncoated	BaWO-501	1300
5 × 5 × 30	Uncoated	BaWO-502	1700
5 × 5 × 50	Uncoated	BaWO-503	2060

Co:Spinel / Cr^{4+}:YAG – PASSIVE Q-SWITCHING CRYSTALS



Cr^{4+}:YAG crystals

Fe:ZnSe, Cr:ZnSe, Co:ZnS solid-state saturable absorbers also are available upon request

Co:Spinel (Co^{2+}:$MgAl_2O_4$) is a relatively new material for passive Q-switching in lasers emitting from 1.2 to 1.6 μm, in particular, for eye-safe 1.54 μm Er:glass laser, but also works at 1.44 μm and 1.34 μm wavelengths. High absorption cross section (3.5×10^{-19} cm^2) permits Q-switching of Er:glass laser without intracavity focusing both with flash-lamp and diode-laser pumping. Negligible excited-state absorption results in high contrast of Q-switch, i.e. the ratio of initial (small signal) to saturated absorption is higher than 10 (Fig. 1).

Cr^{4+}:YAG is one of the best passive Q-switch for high power lasers emitting at ~1 μm wavelength. Standard diameter apertures – 5, 8, 9.5 mm and various initial transmission (or optical density) are available upon request. Also Cr^{4+}:YAG laser rods for ultra-short pulse solid-state lasers are available.

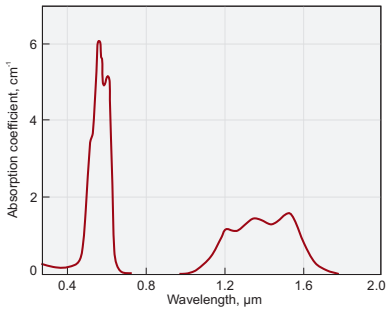


Fig. 1. Absorption spectra of the Co:Spinel crystal

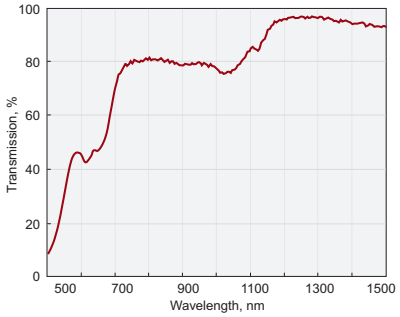


Fig. 2. Transmission of AR coated at 1064 nm Cr:YAG Q-switch with initial transmission of 80% at 1064 nm

SPECIFICATIONS

	Co:Spinel	Cr^{4+}:YAG
Working wavelength range, μm	1.2 – 1.6	0.8 – 1.2
Ground state absorption cross section, cm^2	3.5×10^{-19} (at 1.54 μm)	5×10^{-18} (at 1.06 μm)
Excited state absorption cross-section, cm^2	–	7×10^{-19} (at 1.06 μm)
Initial transmittance, %	30 – 99	20 – 99
Transmission tolerances	±2 %	±2 %
Wavefront distortion	<λ/10 @ 632.8 nm	<λ/8 @ 632.8 nm
Diameter tolerances	+0.0 / -0.2 mm	+0.0 / -0.2 mm
Parallelism error	< 20 arcsec	≤ 30 arcsec
Perpendicularity	< 5 arcmin	≤ 15 arcsec
Surface quality	10 – 5 scratch & dig (per MIL-O-13830A)	20 – 10 scratch & dig (per MIL-O-13830A)
Chamfer	<0.1 mm @ 45°	<0.1 mm @ 45°
AR Coating reflectivity	<0.2 % @ 1540 nm	<0.2 % @ 1064 nm

STANDARD Cr^{4+}:YAG CRYSTALS

Initial Transmission, %	Diameter, mm	Catalogue number	Price, EUR
20	7	CrYAG-07-20	130
30	7	CrYAG-07-30	130
35	7	CrYAG-07-35	130
40	7	CrYAG-07-40	130
45	7	CrYAG-07-45	130
50	7	CrYAG-07-50	130
65	7	CrYAG-07-65	130
70	7	CrYAG-07-70	130
80	7	CrYAG-07-80	130
85	7	CrYAG-07-85	130

STANDARD Co:Spinel CRYSTALS

Initial Transmission, %	Diameter, mm	Catalogue number	Price, EUR
30	5	CoMALO-05-30	725
40	5	CoMALO-05-40	725
50	5	CoMALO-05-50	725
60	5	CoMALO-05-60	725
70	5	CoMALO-05-70	725
80	5	CoMALO-05-80	725
90	5	CoMALO-05-90	725

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