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Optical Components:

Laser Crystals

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Crystals Introduction

Sinoceramics supplies many types of crystals for laser and instrument applications. The crystals we supply fall under the following categories.

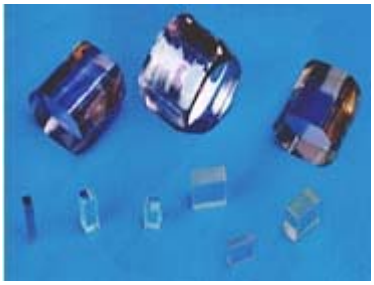
- Laser Crystals
- Nonlinear Crystals
- E-O Crystals
- Photofractive Crystals
- Birefringent Crystals

Applications for these crystals are as follows:

Laser Crystal		Nonlinear Crystal		Optical Crystal	
Name	**Wavelength**	**Name**	**Wavelength**	**Name**	**Transmission Range**
$Nd:YVO_4$	1064nm	BBO	400-300nm	Quartz	2.0
Nd:YAG	1064nm	KTP	490-1800nm	a-BBO	2.0
$Nd:GdVO_4$	1064nm	BiBO	350-2500nm	YVO_4	2.0
Nd:YLF	1047/1053nm	KD*P	500-1500nm	Calcite	3.0
Nb:YAG	1030nm	$LiNbO_3$	900-4500nm	$LiNbO_3$	3.0
Er:YAG	2940nm	$Fe:LiNbO_3$	600-4500nm		
Cr:YAG	800-1200nm	$AgGaS_2$	2000-12000nm		
Ti:Sapphire	795nm				

Nd: YVO_4

Nd:YVO_4 is the most efficient laser crystal for diode-pumped solid-state lasers. Its good physical, optical, and mechanical properties make it an excellent crystal for high power, stable, and cost-effective diode-pumped solid-state lasers.

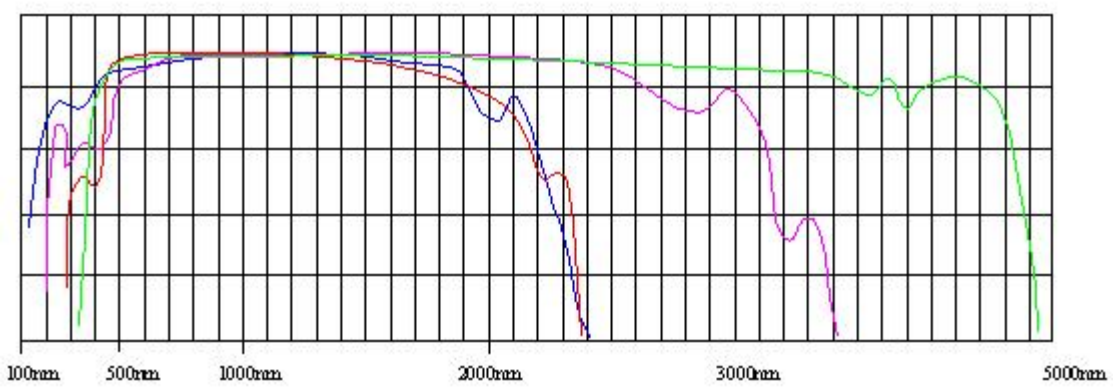


If we compare the Nd:YVO_4 with the Nd:YAG, we find that the Nd:YVO_4 possess:

- Lower lasing threshold and higher slope efficiency
- Large Stimulated emission cross-section at lasing wavelength
- High absorption over a wide pumping wavelength bandwidth
- Low dependency on pumping wavelength and tend to single mode output
- Optically uniaxial and large birefringence emit strongly-polarized laser

Basic Properties
Atomic Density: 1.26×10^{20} atoms/cm^3 (Nd 1.0%)
Crystal Structure: Zircon Tetragonal, space group D_{4h}-I_4/amd
a = b = 7.1193, c = 6.2892
Density: 4.22g/cm^3
Mohs Hardness: 4-5
Thermal Expansion Coefficient (300K): $a_a = 4.43 \times 10^{-6}$/K, $a_c = 11.37 \times 10^{-6}$/K
Thermal Conductivity Coefficient (300K): up C: 0.0523W/cm/K, deg C: 0.0510W/cm/K

Optical Properties: (for 1.1 atm% Nd:YVO_4, a-cut)
Lasing Wavelength: 1064nm, 1342nm
Thermal Optical Coefficient (300K): $dn_o/dT = 8.5 \times 10^{-6}$/K, $dn_e/dT = 2.9 \times 10^{-6}$/K
Stimulated Emission Cross-Section: $25 \times 10^{-19}cm^2$ @ 1.064m
Fluorescent Lifetime: 90ms
Absorption Coefficient: $31.4cm^{-1}$ @ 810nm
Intrinsic Loss: $0.02cm^{-1}$ @ 1064nm
Gain Bandwidth: 0.96nm @ 1064nm
Polarized Laser Emission: p polarization; parallel to optic axis (c-axis)
Diode Pumped Optical to Optical Efficiency: > 60%



Sellmeir Equations for Pure YVO4 Crystal:

$n_o^2 = 3.77834 + 0.069736 / (\lambda^2 - 0.04724) - 0.0108133\lambda^2$

$n_e^2 = 4.59905 + 0.110534 / (\lambda^2 - 0.04813) - 0.0122676\lambda^2$

Laser Properties: :

The Nd:YVO_4 crystal has large stimulated emission cross-sections at both 1064nm and 1342nm. The stimulated emission cross-section of an a-axis cut at 1064nm is about 4 times higher than that of the Nd:YAG crystal. However the lifetime of Nd:YVO_4 is about 2.7 times shorter than that of Nd:YAG. Because of its high pump quantum efficiency, the slope efficiency of Nd:YVO_4 can be very high if the laser cavity is properly designed. The table below lists the major laser properties of Nd:YVO_4 in comparison to the properties of Nd:YAG.

Laser Crystal	Doping (atm%)	s ($x10^{-19}cm^2$)	a ($cmx10^{-1}$)	T (ms)	L (mm)	P_{th} (mW)	h_s (%)
Nd:YVO_4 (a-cut)	1.0	25	31.2	90	0.32	30	52
	2.0	25	72.4	50	0.14	78	48.6
Nd:YVO_4 (c-cut)	1.1	7	9.2	90	.	231	45.5
Nd:YAG	0.85	6	7.1	230	1.41	115	38.6

Typical Results

Diode Pumped Nd:YVO_4 Laser Output Comparing with Diode Pumped Nd:YAG Laser

Crystals	Size (mm^3)	Pump Power	Output (at 1064nm)
Nd:YVO_4	3x3x1	850mW	350mW
Nd:YVO_4	3x3x5	15W	6W
Nd:YAG	3x3x2	850mW	34mW

Diode Pumped Nd:YVO_4 and KTP Green Laser

Nd:YVO_4 (mm^3)	KTP (mm^3)	Pump Power	Output (TEM_{00} at 532nm)
3x3x1	3x3x5	890mW	76mW
3x3x1	3x3x5	50mW	2.5mW

1. A threshold of 78mW and a slope efficiency of 48.5% at 1.064mm was obtained by using an a-cut 3mm long Nd:YVO_4 crystal with output coupler R = 96%. Under the same conditions, a 5mm long Nd:YAG crystal has a threshold of 115mW and a slope efficiency of 28.6%
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2. Recently, over 30W of TEM_{00} output power was achieved by using an a-cut Nd:YVO_4 and pumped by 60W fiber coupled diode lasers. The optical conversion efficiency exceeds 50%. High power and stable infrared output @ 1064nm and 1342nm has been achieved with diode pumped Nd:YVO_4 lasers.
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3. Single-longitudinal-mode oscillation of a Nd:YVO_4 microchip laser has been achieved with high power and high slope efficiency. Such a single mode source has been developed for the use of a master oscillator for injection locking of Nd laser systems.
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4. Because of its large stimulated emission cross section at 1.34mm, Nd:YVO_4 is also an efficient laser crystal for diode laser-pumped 1.3mm laser. By using 1mm long Nd:YVO4 crystal and being pumped by an 850mW diode laser at 808nm, a 50mW output at 1.34mm has been observed. Compared to the 34mW output from a 2mm long Nd:YAG

Nd:YVO_4 Specifications

- Transmitting Wavefront Distortion: < 1/4 @ 633nm
- Dimension Tolerance: W-0.1mm x H-0.1mm x L +0.2mm/-0.1
- Clear Aperture: > 90% central area
- Flatness: 1/8 @ 633nm, and 1/4 @ 633nm for thickness < 2mm
- Scratch/Dig code: 10/5 to MIL-O-13830A
- Parallelism: Better than 5 arc minutes
- Perpendicularity: 5 arc minutes
- AR Coating: R < 0.2% @ 1064nm
- HR Coating: R > 99.8% @ 1064nm, T > 95% @ 808nm
- Quality Warranty Period: One year under proper use

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Nd:YAG

Nd:YAG crystal is the most widely used laser crystal on solid-state lasers. Sinoceramics is able to supply the quality of Nd:YAG rods with high optical homogeneity, consistent performance, high processing accuracy and on time delivery.

Basic Properties (1.0 atm% Nd doped)

Chemical Formula:	Nd:$Y_3Al_5O_{12}$
Crystal Structure:	Cubie
Lattice Constants:	12.01 A
Concentration:	~$1.2x10^{20}cm^{-3}$
Melting Point:	1970°C
Density:	4.56 g/cm^3
Mohs Hardness	8.5
Refractive Index	1.82 @ 1.64nm
Thermal Expansion Coefficient	$7.8x10^{-6}$/K[111],0 -250°C
Thermal Conductivity	14W/m /K @ 20°C, 10.5W/m /K @ 100°C
Lasing Wavelength	1064nm
Stimulated Emission Cross Section	$2.8x10^{-19}cm^{-2}$
Relaxation Time of Terminal Lasing Level	30ns
Radiative Lifetime	550ms
Spontaneous Fluorescence	230ms
Loss Coefficient	0.003 cm^{-1} @ 1064nm
Effective Emission Cross Section	$2.8x10^{-19}cm^2$
Pump Wavelength	807.5nm
Absorption Band at Pump Wavelength	1nm
Line Width	0.6nm
Polarized Emission	Unpolarized

Standard Products Specification

Dopant Concentration (atomic %):	0.9% - 1.1%
Orientation:	<111> crystalline direction
Wavefront Distortion:	1/8 per inch @ 633nm
Extinction Ratio :	> 28dB
Dimension Tolerance:	± 0.05mm for diameter, ± 0.2mm for length
Parallelism:	< 10 arc seconds
Perpendicularity:	< 5 arc minutes
Surface Quality:	10-5 scratch and dig
Surface Flatness:	< λ /10 @ 633 nm
AR Coating:	R < 0.1% @ 1064nm
Damage Threshold:	> 500MW/cm^2 @ 1064nm, 10ns, 10Hz

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Nd:YLF

Optical Properties

Transparency Range:	180-6700nm
Peak Stimulated Emission Cross Section:	$1.8x10^{-19}cm^2$ (E||C) @ 1064nm $1.2x10^{-19}cm^2$ ($E_{perp}C$) @ 1064nm
Spontaneous Fluorescence Lifetime:	485 µs for 1% Nd doping
Seatter Losses:	< 0.2% per cm
Peak Absorption Coefficient (for 1.2% Nd):	$a = 10.8cm^{-1}$ (792.0nm E||C) $a = 3.59cm^{-1}$ (792.0nm $E_{perp}C$)
Laser Wavelength:	1047nm (||c, a-cut crystal) 1053nm ($_{perp}$c, a-cut crystal)

Physical

Chemical Formula:	$LiY_{1.0-x}Nd_xF_4$
Space Group:	$14_{1/a}$
Nd atoms/m^3:	$1.4x10^{20}$ atoms/cm^3 for 1% Nd doping
Modulus of Elasticity:	85GPa
Crystal Structure:	Tetragonal
Cell Parameters:	a = 5.16A , c = 10.85A
Melting Point:	819°C
Mohs Hardness:	4 - 5
Density:	$3.99g/cm^3$
Thermal Conductivity:	0.063W/m /K
Specific Heat:	0.79J/gK
Thermal Conductivity:	$8.3x10^{-6}$/K||C $13.3x10^{-6}/K_{perp}C$

Index of Refraction

Wavelength	n_a	n_c
262nm	1.485	1.511
350nm	1.473	1.491
525nm	1.456	1.479
1050nm	1.448	1.470
2065nm	1.442	1.464

dn/dT

Wavelength	E||C	$E_{perp}C$
436nm	$-2.44x10^{-6}$/°C	$-0.54x10^{-6}$/°C
578nm	$-2.86x10^{-6}$/°C	$-0.91x10^{-6}$/°C
1060nm	$-4.30x10^{-6}$/°C	$-2.00x10^{-6}$/°C

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The Sellmeier Equations (λ in μm)

$n_o^2 = 1.38757 + 0.70757\lambda^2 / (\lambda^2 - 0.00931) + 0.18849\lambda^2 / (\lambda^2 - 50.99741)$

$n_e^2 = 1.31021 + 0.84906\lambda^2 / (\lambda^2 - 0.00876) + 0.53607\lambda^2 / (\lambda^2 - 134.9566)$

Sinoceramics's Nd:YLF Production Capabilities:

- Rod sizes from 2mm-10mm in diameter and from 1mm-150mm in length
- Orientation of rod axis to crystal axis is within 1°
- Polished only or AR coated rods
- Nd dopant concentrations between 0.4-1.2%
- Large rod and slab dimensions and non-standard dopant concentrations are available upon request

Specifications

Standard Dopant:	1.1 ± 0.1%
Wavefront Distortion:	< λ /4 per inch @ 633nm
Parallelism:	< 10 arc seconds
Perpendicularity:	< 5 arc minutes
Chamfer:	0.13 ± 0.07mm @ 45°
Surface Quality:	0/5 scratch and dig
End Coating:	R < 0.15% @ 1047/1053nm
Surface Flatness:	λ /8 @ 532.8nm

Cr:YAG

Cr^{4+}:YAG is an excellent crystal for passively Q-switching diode pumped or lamp-pumped Nd:YAG, Nd:YLF, Nd:YVO_4, or other Nd and Yb doped lasers at a wavelength of 0.8-1.2μm. Because of its high damage threshold (> 500MW/cm^2) and being easy to be operated, it will replace LiF and Dye which are commonly used as passive Q-switching materials.

Basic Properties of Cr^{4+}:YAG

Molecular Formula:	$Cr^{4+}:Y_3Al_5O_{12}$
Crystal Structure:	Cubic Granet
Density:	4.56g/cm^2
Hardness:	8.5 (Mohs)
Damage Threshold:	> 500MW/cm^2
Reflective Index:	1.82 @ 1064nm

Sinoceramics provides Cr^{4+}:YAG with Cr^{4+} doping level from 0.5 - 3mol%. The size could be from 2x2 mm^2 with length from 0.1 - 12mm. AR-coatings and HR-coatings are also available. We can control the transmission from 1% to 99% according to the customers' requests.

For Cr:YAG, the pulse width of passively Q-switched lasers could be as short as 5ns for diode pumped Nd:YAG lasers and repetition as high as 10kHz for diode pumped Nd:YVO_4 lasers. Furthermore, an efficient green output at 532nm and UV output at 355nm and 266nm were generated, after a subsequent intra-cavity SHG in KTP or LBO, THG in LBO, or BBO and 4HG in BBO for diode pumped, passive Q-switched Nd:YAG and Nd:YVO_4 lasers.

Cr:YAG is also a laser crystal with tunable output from 1.35-1.6mm. It can generate ultra short pulse laser (to femtosecond pulsed) when pumped by Nd:YAG laser at 1064mm

Cr^{4+}:YAG crystal has been demonstrated as a self-pumped phase-conjugate mirror in a nanosecond Nd:YAG high power loop resonator. It compensates not only for phase aberrations, but also for polarization aberrations induced into the loop resonator.

Specifications

Flatness:	< λ /8 @ 633nm
Wavefront Distortion:	< λ /4 @633nm
Parallelism:	< 30"
AR-Coating:	R < 0.2% @ 1064nm
Surface Quality:	10/5 to MIL-O-13830A
Transmission Tolerance:	T ± 3%