Neodymium Doped Yttrium Orthavanadate ($Nd:YVO_4$) Crystal

Laser crystals are used to generate laser radiation. The commonly used laser crystals include Nd:YAG, $Nd:YVO_4$ and Nd:YLF for near IR lasers, and Ti:Sapphire for tunable near IR output. Specifically, $Nd:YVO_4$, for diode pumped solid state lasers were developed because diode pumping attracts more and more interest of both R&D and OEM customers. The laser crystals supplied include $Nd:YVO_4$, Nd:YAG, Gr:YAG, etc. We also provide complete kits of crystals and optics for assembling your diode pumped solid state lasers.

$Nd:YVO_4$ is one of the most efficient laser host crystal currently existing for diode laser-pumped solid-state lasers. Its large stimulated emission cross-section at lasing wavelength, high absorption coefficient and wide absorption bandwidth at pump wavelength, high laser induced damage threshold as well as good physical, optical and mechanical properties make $Nd:YVO_4$ an excellent crystal for high power, stable and cost-effective diode pumped solid-state lasers. Developments have shown that $Nd:YVO_4$ can produce powerful and stable IR, green, blue lasers with the design of $Nd:YVO_4$ and frequency doubling crystals.

Compared with Nd:YAG and Nd:YLF for diode laser pumping, $Nd:YVO_4$ lasers possess the advantages of lower dependency on pump wavelength and temperature control of a diode laser, wide absorption band, higher slope efficiency, lower lasing threshold, linearly polarized emission and singlemode output. For the applications in which more compact design and the single-longitudinal-mode output are needed, $Nd:YVO_4$ shows its particular advantages over other commonly used laser crystals. The diode laser-pumped $Nd:YVO_4$ compact laser and its frequency-doubled green, red or blue laser light will be the ideal laser tools of machining, material processing, spectroscopy, wafer inspection, light show, medical diagnostics, laser printing and the most widespread applications.

With advanced technology to grow high optical quality and large size $Nd:YVO_4$ crystals, we can consistently provide as large as ϕ 35x50 mm^3 $Nd:YVO_4$ bulk crystal and ϕ 20x20 mm^3 finished crystal with very low intrinsic optical loss.

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LASER COMPONENTS

Main Features

- Low lasing threshold and high slope efficiency
- Large stimulated emission cross-section at lasing wavelength
- High absorption over a wide pumping wavelength bandwidth
- Optically uniaxial and large birefringence emits polarized laser light

Basic Properties

Atomic density	~1.37 x 10^{20} atoms/cm^2
Crystal structure	zircon tetragonal, space group D_{4h}, a = b = 7.12, c = 6.29
Density	4.22 g/cm^3
Mohs hardness	glass-like, ~5
Thermal expansion coefficient	α_a = 4.43 x 10^{-6}/K, α_c = 11.37 x 10^{-6}/K
Thermal conductivity coefficient	∥C: 5.23 W/m/K; ⊥C: 5.10 W/m/K

Optical Properties (typically for 1.1 atm% $Nd:YVO_4$, a-cut crystals)

Lasing wavelengths	914 nm, 1064 nm, 1342 nm
Crystal class	positive uniaxial, $n_o = n_a = n_b$, $n_e = n_c$, n_o = 1.9573, n_e = 2.1652, @ 1064 nm n_o = 1.9721, n_e = 2.1858, @ 808 nm n_o = 2.0210, n_e = 2.2560, @ 532 nm
Sellmeier equation (for pure YVO_4 crystals)	$n_o^2 = 3.77834 + 0.069736/(\lambda 2 - 0.04724) - 0.0108133.\lambda^2$ $n_e^2 = 4.59905 + 0.110534/(\lambda 2 - 0.04813) - 0.0122676.\lambda^2$
Thermal optical coefficient	dn_a/dT = 8.5 x 10^{-6}/K, dn_c/dT = 3.0 x 10^{-6}/K
Stimulated emission cross-section	25.0 x 10^{-19} cm^2 , @1064 nm
Fluorescent lifetime	90 µs (about 50 µs for 2 atm% Nd doped) @ 808 nm
Absorption coefficient	31.4 cm^{-1} @ 808 nm
Absorption length	0.32 mm @ 808 nm
Intrinsic loss	Less 0.1% cm^{-1} , @1064 nm
Gain bandwidth	0.96 nm (257 GHz) @ 1064 nm
Polarized laser emission	π polarization; parallel to optic axis (c-axis)
Diode pumped optical to optical efficiency	>60%

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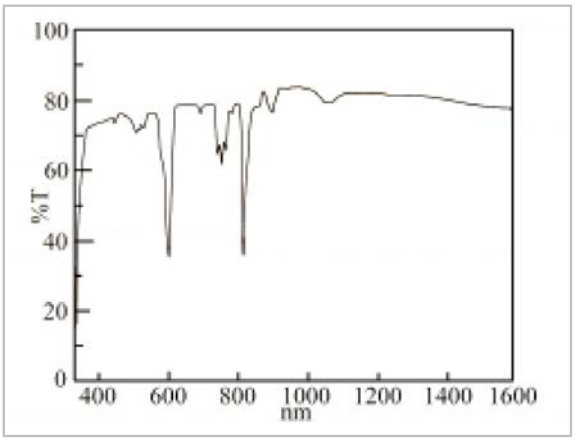
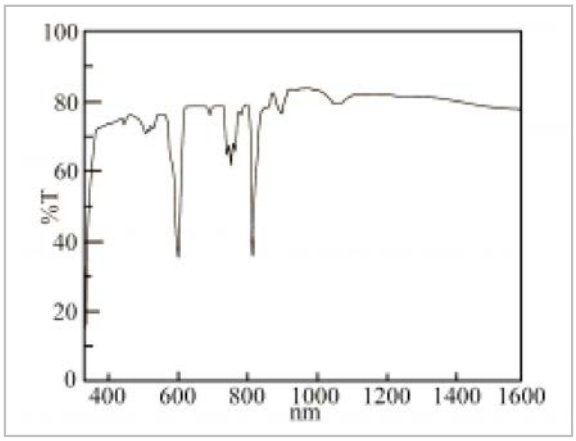
Absorption Curves of Different Doping $Nd:YVO_4$

$Nd:YVO_4$ shows high absorption coefficients at pumping wavelengths. Therefore, a crystal shortin-length (e.g. 1mm) is preferred, and more compact lasers can be constructed by using $Nd:YVO_4$ than using Nd:YAG. Furthermore, it has a wide and smoothly-varied bandwidth of absorption, so that it allows of less stringent requirements of diode laser selection and wavelength control as compared with Nd:YAG. Different doping levels $Nd:YVO_4$ are shown as follows.

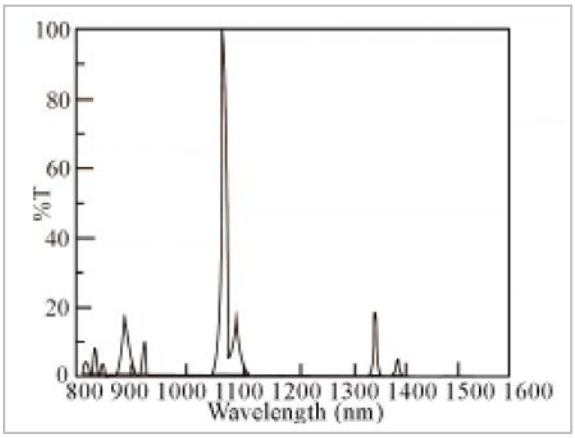


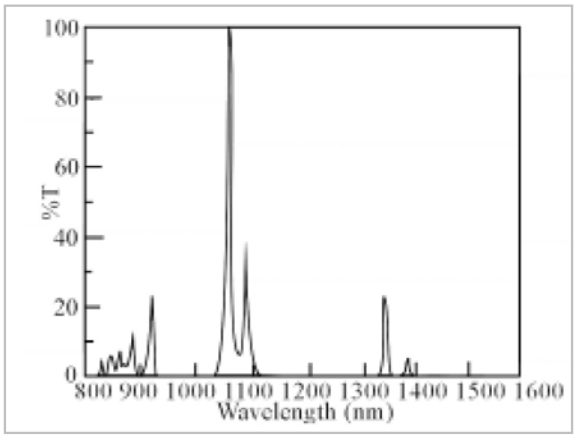
Absorption curve of 0.5 % doping YVO_4
(Thickness: 1 mm)



Absorption curve of 3% doping YVO_4
(Thickness: 1 mm)

Fluorescence Spectra Curve





Normalized fluorescence spectra from 800 nm to 1600 nm of Nd 1.1 at. % doped $Nd:YVO_4$ for π polarization (a) and for σ polarization (b).

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Laser Properties

The $Nd:YVO_4$ crystal has large stimulated emission cross-sections (σ) at both 1.06 µm and 1.3 µm. The stimulated emission cross-section of an a-axis cut $Nd:YVO_4$ crystal at 1.064 µm is about 4 times that of the Nd:YAG crystal. Although the lifetime (τ) of $Nd:YVO_4$ is about 2.7 times shorter than that of Nd:YAG, a figure of merit (FOM) for minimum threshold of a-cut $Nd:YVO_4$, which is proportional to the $\sigma\tau$ products, is reasonably higher than that of Nd:YAG crystal. Because of its high pump quantum efficiency (η_p), the slope efficiency of $Nd:YVO_4$ can be very high if the laser cavity is properly designed. The following table lists the major laser properties of $Nd:YVO_4$ in comparison with those of Nd:YAG.

Laser Properties of Nd: YVO_4 Crystals vs. Nd:YAG

Laser crystal	Nd doped (atm%)	σ ($x10^{-19}$ cm^2)	α (cm^{-1})	τ µs	l_α (mm)	P_{th} (mw)	η_s (%)
$Nd:YVO_4$ (a-cut)	1.1 2.0	25	31.2 72.4	90 50	0.32 0.14		
$Nd:YVO_4$ (c-cut)	1.1	7	9.2	90		231	45.5
Nd:YAG	0.85	6	7.1	230	1.41	115	38.6

Furthermore, the 1.34 µm CW operation of the $Nd:YVO_4$ laser completely outperformed that of Nd:YAG at 1.32 µm because of an 18 times larger stimulated cross-section.
$Nd:YVO_4$ crystal has a low thermal conductivity coefficient, therefore, long-in-length with low dopant level $Nd:YVO_4$ is recommended for high power diode laser application in order to reduce thermal lasing effects. Gold metalization on the side of $Nd:YVO_4$ crystals is the solutions not only for thermal lasing effects for high power pumped, but also enhancing lasing mode of the laser.

Diode Laser-Pumped $Nd:YVO_4$ Lasers

- A threshold of 78 mW and a slope efficiency of 48.5% at 1.064 µm were obtained by using an a-cut 3 mm long $Nd:YVO_4$ crystal with output coupler R = 96%. Under the same conditions, a 5 mm long Nd:YAG crystal has a threshold of 115 mW and a slope efficiency of 38.6%.
- Recently, over 30 W of TEM_{00} output power was achieved by using a-cut $Nd:YVO_4$ and pumped by 60 W fiber coupled diode lasers. The optical conversion effciency exceeds 50%. High power and stable infrared output @ 1064 nm and 1342 nm has been available with diode pumped $Nd:YVO_4$ lasers.
- 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.
- Because of its large stimulated emission cross section at 1.34 µm, $Nd:YVO_4$ is also an efficient laser crystal for diode laser-pumped 1.3 µm laser. By using 1 mm long $Nd:YVO_4$ crystal and pumped by an 850 mW diode laser at 808 nm, 50 mW output at 1.34 µm has been observed, compared to 34 mW from 2 mm long Nd:YAG.

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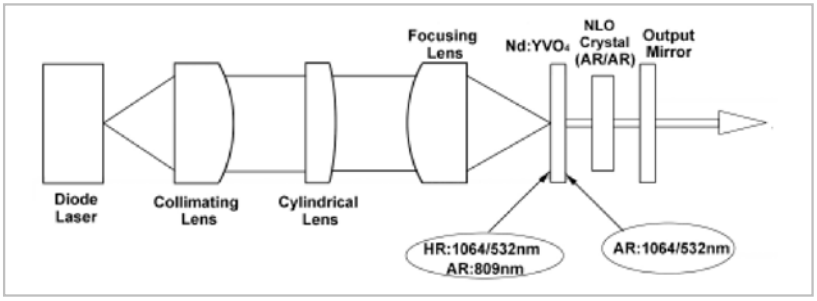

Basic experimental scheme of diode laser pumped $Nd:YVO_4$ green laser

Frequency-Doubled $ND:YVO_4$ Lasers

- By using the compact design of $Nd:YVO_4$ + KTP crystals, high power green or red light output can be generated in a diode laser pumped $Nd:YVO_4$ laser. When pumped by a 890 mW diode laser, more than 76 mW single mode (TEM_{00}) green output was obtained with a 3x3x1 mm^3 $Nd:YVO_4$ and a 3x3x5 mm^3 intracavity KTP.
- Diode pumped green lasers has been commercialized with the compact design of $Nd:YVO_4$ + KTP crystals. 2.5 mW green output was achieved in a $Nd:YVO_4$ microchip laser with a very short (9 mm) laser cavity when pumped by a 50 mW diode laser.
- Over 10 W and high stable CW green output @ 532 nm was commerially available with diode pumped $Nd:YVO_4$ and frequency double using NCPM LBO crystals. Single longitudinal mode (SLM) green output, Q-switched green and UV outputs were also obtained.
- Over 400 mW blue laser @ 457 nm based on $Nd:YVO_4$+ BBO crystals, is commerical available.

Standard Specifications of $Nd:YVO_4$ Crystals

Nd:Dopant level	0.1 – 3.0 atm%
Standard dimensions	3x3x3 mm^3, 3x3x1 mm^3, 3x3x0.5 mm^3
Wavefront distortion	<λ/8 at 633 nm
Scattering dites	invisible, probed with a He-Ne laser
Orientation	±0.5 deg
Dimensional tolerance	+0.1/– 0.1 mm
End-faces configuration	plano/plano
Surface quality	10/5 scratch/dig per MIL-O-13830 B
Flatness	λ/10 at 633 nm
Clear aperture	>central 90%
Parallelism	<10 arc sec.
Intrinsic loss	<0.1% cm^{-1}

Note:
Other specifications of $Nd:YVO_4$ crystals and coatings are available upon request.

We provide the complete diode pumped laser kits, including laser crystals ($Nd:YVO_4$ and Nd:YAG), NLO crystals (KTP and BBO) and laser optics.

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