Nd:YVO_4 - Neodymium Doped Yttrium Orthovanadate

Introduction

Neodymium Doped Yttrium Orthovanadate (Nd:YVO_4) is the most efficient laser host crystal for diode pumping among the current commercial laser crystals, especially, for low to middle power density. This is mainly for its absorption and emission features surpassing Nd:YAG. Pumped by laser diodes, Nd:YVO_4 crystal has been incorporated with high NLO coefficient crystals (LBO, BBO, or KTP) to frequency-shift the output from the near infrared to green, blue, or even UV. This incorporation to construct all solid state lasers is an ideal laser tool that can cover the most widespread applications of lasers, including machining, material processing, spectroscopy, wafer inspection, light displays, medical diagnostics, laser printing, and data storage, etc. It has been shown that Nd:YVO_4 based diode pumped solid state lasers are rapidly occupying the markets traditionally dominated by water-cooled ion lasers and lamp-pumped lasers, especially when compact design and single-longitudinal-mode output are required.

Nd:YVO_4's advantages over Nd:YAG

- As high as about five times larger absorption efficient over a wide pumping bandwidth around 808 nm (therefore, the dependency on pumping wavelength is much lower and a strong tendency to the single mode output)
- As large as three times larger stimulated emission cross-section at the lasing wavelength of 1064 nm.
- Lower lasing threshold and higher slope efficiency.
- As a uniaxial crystal with large birefringence, the emission is only linearly polarized.

CASTECH Provides

- Various doping concentrations from 0.1 to 3%.
- Doping concentration tolerance: ± 0.05% (at.%<1%), ± 0.1% (at.% ≧1%)
- High quality Nd:YVO_4 crystals size up to Φ20 x 40 mm^3
- 10,000 pcs of Nd:YVO_4 devices per month in sizes 3x3x0.5mm^3 to 4x4x30 mm^3
- Fast delivery
- Competitive price

Figure 1. Absorption Curve of 0.5% Nd:YVO_4 (thickness 4 mm)

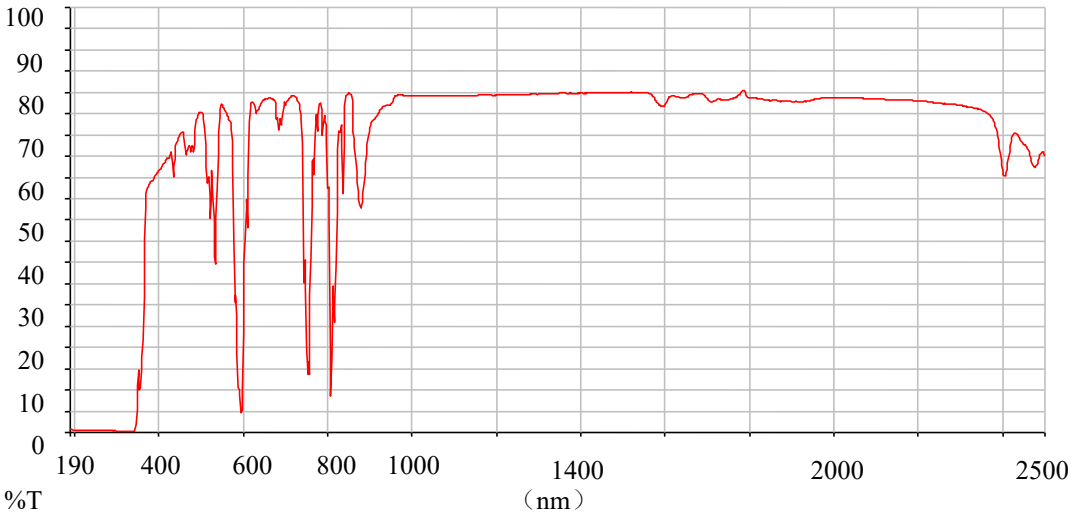

Table 1. Basic Properties

Crystal Structure	Zircon Tetragonal, space group D_{4h}-I4/amd
Lattice Parameter	a = b = 7.1193 Å, c = 6.2892 Å
Density	4.22 g/cm^3
Atomic Density	1.26 ×10^{20} at/cm^3 (Nd 1.0%)
Mohs Hardness	4-5 Mohs (Glass-like)
Thermal Expansion Coefficient (300K)	α_a = 4.43 × 10^{-6}/K α_c = 11.37 × 10^{-6}/K
Thermal Conductivity Coefficient (300K)	// C: 5.23 W/m/K ⊥C: 5.10 W/m/K
Lasing Wavelength	1064 nm, 1342 nm
Thermal Optical Coefficient (300K)	dn_o/dT = 8.5 × 10^{-6} /K dn_e/dT = 2.9 × 10^{-6} /K
Stimulated Emission Cross-section	25 x 10^{-19} cm^2 @1064 nm
Fluorescent Lifetime	90 μs (1% Nd doped)
Absorption Coefficient	31.4 cm^{-1} @810 nm
Intrinsic Loss	0.02 cm^{-1} @1064 nm
Gain Bandwidth	0.96 nm @1064 nm
Polarized Laser Emission	π polarization; parallel to optical axis (c-axis)
Diode Pumped Optical to Optical Efficiency	> 60%
Sellmeier Equations (λ in μm)	$n_o^2 = 3.77834 + 0.069736 / (\lambda^2 - 0.04724) - 0.010813\ \lambda^2$ $n_e^2 = 4.59905 + 0.110534 / (\lambda^2 - 0.04813) - 0.012676\ \lambda^2$

Laser Properties of Nd:YVO_4

1. One most attractive character of Nd:YVO_4 is, compared with Nd:YAG, its 5 times larger absorption coefficient in a broader absorption bandwidth around the 808 nm peak pump wavelength, which just matches the standard of high power laser diodes currently available. This means a smaller crystal that could be used for the laser, leading to a more compact laser system. For a given output power, this also means a lower power level at which the laser diode operates, thus extending the lifetime of the expensive laser diode. The broader absorption bandwidth of Nd:YVO_4 which may reaches 2.4 to 6.3 times that of Nd:YAG. Besides more efficient pumping, it also means a broader range of selection of diode specifications. This will be helpful to laser system makers for wider tolerance for lower cost choice.

2. Nd:YVO_4 crystal has larger stimulated emission cross-section, both at 1064 nm and 1342 nm. When a-axis cut Nd:YVO_4 crystal lasing at 1064 nm, it is about 4 times higher than that of Nd:YAG, while at 1340 nm the stimulated cross-section is 18 times larger, which leads to a CW operation completely outperforming Nd:YAG at 1320 nm. These make Nd:YVO_4 laser be easy to maintain a strong single line emission at the two wavelengths.

3. Another important character of Nd:YVO_4 lasers is, because it is an uniaxial rather than a high symmetry of cubic as Nd:YAG, it only emits a linearly polarized laser, thus avoiding undesired birefringent effects on the frequency conversion. Although the lifetime of Nd:YVO_4 is about 2.7 times shorter than that of Nd:YAG, its slope efficiency can be still quite high for a proper design of laser cavity, because of its high pump quantum efficiency.

The major laser properties of Nd:YVO_4 vs Nd:YAG are listed in Table 2 below, including stimulated emission cross-sections(σ), absorption coefficient (α), fluorescent lifetime (τ), absorption length (L_α), threshold power (P_{th}) and pump quantum efficiency (η_S).

Table 2. Laser Properties of Nd:YVO_4 vs Nd:YAG

Laser Crystal	Doping (at.%)	σ ($\times 10^{-19}cm^2$)	α (cm^{-1})	τ (μs)	L_α (mm)	P_{th} (mW)	η_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

Nd:YVO_4's parameters

Table 3. Specifications

Dimension Tolerance	(W ± 0.1 mm) × (H ± 0.1 mm) × (L + 0.5/-0.1 mm) × (L≧2.5 mm) (W ± 0.1 mm) × (H ± 0. 1 mm) × (L + 0.1/-0.1 mm) × (L＜ 2.5mm)
Clear Aperture	Central 90% of the diameter
Surface Quality (Scratch/Dig)	10/5 to MIL-PRF-13830B
Flatness	≦λ/8 @633 nm (L≧2.5 mm) ≦λ/4 @633 nm (L<2.5 mm)
Transmitted Wavefront Distortion	≦λ/4 @633 nm
Parallelism	20 arc sec
Perpendicularity	≦15 arc min
Angle Tolerance	≦± 0.5°
Chamfer	≦0.2 mm × 45°
Chip	≦0.1 mm
Damage Threshold	＞1 GW/cm^2 @1064 nm, 10 ns, 10 Hz (AR-coated)
Quality Warranty Period	One year under proper use

CASTECH provides the following coatings

- Both ends AR/AR-1064/808 nm, R<0.2% @1064 nm, R<0.5% @808 nm, or R<0.1% @1064 nm, R<3% @808 nm
- S1: HR-1064/532 nm, HT-808 nm, R>99.8% @1064/532 nm, T>90% @808 nm
  S2: AR-1064/532 nm, R<0.2% @1064 nm, R<0.5% @532 nm
- S1: HR-1064 nm, HT-808 nm, R>99.8% @1064 nm, T>95% @808 nm
  S2: AR-1064 nm, R<0.1% @1064 nm
- S1, S2 AR-coated, S3: gold/chrome plated
- Both ends AR/AR-1064 nm; S3: AR-808 nm
- Other coatings are available upon request