Nd:YVO_4

Yttrium Vanadate (or orthovanadate) doped with Neodymium, Nd:YVO_4, is a promising material for diode pumped lasers. Several advantages over Nd:YAG include a **higher gain cross-section**, **lower threshold, a wider Nd absorption peak and polarized output.** The wider absorption peak means that the laser output power is less sensitive to drifting of the diode pump wavelength due to temperature or ageing effects. One optimum pump wavelength is central at 809 nm with a useful range (at 50% of the peak) of 801 to 821 nm. Similarly Nd:YAG peaks at 809 nm, but its range is only 805 to 810 nm.

AOTK uses Cz method technology to grow Nd:YVO_4 crystal. The crystal is tetragonal which means there are two equivalent "a" directions and a "c" direction, all mutually orthogonal. A typical laser rod is oriented with the rod axis along an a-axis of the crystal. Maximum absorption of pump light occurs for polarization along the c-axis.

AOTK Provides:

- Nd doping concentration from 0.1at% to 3at%
- Various size bulk and finished high quality Nd:YVO_4 crystals up to Φ35x50mm^3 and Φ20x25mm^3, respectively
- 30,000 pcs of Nd:YVO_4 devices per month in sizes 3x3x0.5 to 4x4x25 mm^3

Nd:YVO_4 advanced properties

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

Basic Properties

1. Structural and Physical Properties

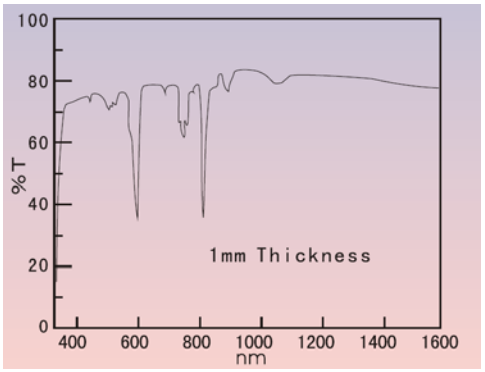
Crystal Structure	Zircon Tetragonal, Space group D_{th}
Lattice Parameters	a=b=7.12Å, c=6.29Å
Mohs Hardness	~5 (Glass - like)
Atomic Density	1.26x10^{20} atoms/cm^3 (Nd 1.0at%)
Density	4.22 g/cm^3
Melting Point	1825°C
Thermal Expansion Coefficient	α_a = 4.43 x 10^{-6} /K; α_c = 11.37 x 10^{-6} /K
Thermal Conductivity	//C: 523W/m/K, ⊥C: 5.10W/m/K

2. Optical Properties

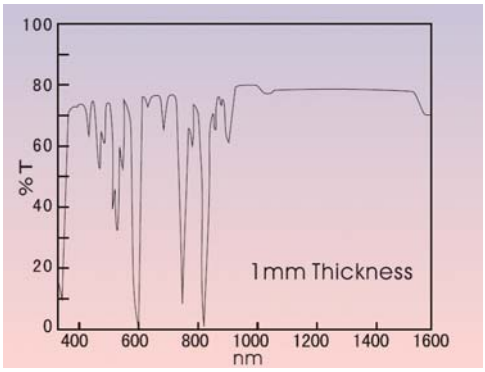
Lasing Wavelength	1064nm, 1342nm, 914nm
Crystal Class	Positive uniaxial, $n_o=n_a=n_b$, $n_e=n_c$
Sellmeier Equation (for pure YVO_4 crystal)	$n_o^2 = 3.77834+0.069736/(\lambda^2-0.04724)-0.0108133\lambda^2$ $n_e^2 = 4.59905+0.110534/(\lambda^2-0.04813)-0.0122676\lambda^2$
Refractive Indexes	n_o = 1.9573, n_e = 2.1652 at 1064 nm n_o = 1.9721, n_e = 2.1858 at 808 nm n_o = 2.0210, n_e = 2.2560 at 532 nm
Thermal Optical Coefficient	dn_a/dT = 8.5x10^{-6}/°C; dn_c/dT = 3.0x10^{-6}/°C
Absorption Coefficient	31.4 cm^{-1} at 808 nm

Absorption Length	0.32 mm at 808 nm
Intrinsic Loss	0.02 cm^{-1} at 1064 nm
Gain Bandwidth	0.96 nm (257 GHz) at 1064 nm
Fluorescence Lifetime	~ 90 μs at 808 nm
Polarized Laser Emission	π polarization, parallel to optic axis (C-axis)
Stimulated Emission Cross-Section	$2.5x10^{-19}$ cm^2 at 1064 nm

Absorption Curves of Different Doping $Nd:YVO_4$



Absorption Curve of Nd 0.5 atm% Doping YVO_4



Absorption Curve of Nd 3 atm% Doping YVO_4

$Nd:YVO_4$ crystal shows very high absorption coefficients at pumping wavelengths. A crystal short-in-length (e.g. 1mm) is preferred, and more compact lasers can be constructed by applying $Nd:YVO_4$ than applying Nd:YAG. Furthermore, it has a wide and smoothly-varied bandwidth of absorption, so it allows of less stringent requirements of diode laser selection and wavelength control as compared with Nd:YAG.

Laser Properties

$Nd:YVO_4$ crystal has large stimulated emission cross-sections (σ) at 1064 nm & 1342 nm. The stimulated emission cross-section of an a-axis cut $Nd:YVO_4$ crystal at 1064 nm is about 4 times that of the Nd:YAG crystal. Due to its high pump quantum efficiency, the slope efficiency of $Nd:YVO_4$ can be very high when the laser cavity is properly designed. The major laser properties of $Nd:YVO_4$ in comparison with that of Nd:YAG are listed as following table .

Laser properties of $Nd:YVO_4$ and Nd:YAG

Laser Crystal	Nd Doped (atm%)	σ ($x10^{-19}$ cm^2)	α (cm^{-1})	τ (μs)	lα (mm)	P_{th} (mW)	η_s (%)
$Nd:YVO_4$ A-cut	1.1	25	31.2	90	0.32	78	48.6
$Nd:YVO_4$ A-cut	2.0	25	72.4	50	0.14	78	
$Nd:YVO_4$ C-cut	1.1	7	9.2	90		231	45.5
Nd:YAG	0.9	6.0	7.1	230	1.41	115	38.7

Main Application-DPSS Lasers

In compact cavity design of $Nd:YVO_4$+KTP, high power green output can be obtained in a diode-pumped $Nd:YVO_4$ laser. 3x3x1 mm3 pumped by 1W diode laser, more than 250 mW TEM_{00} 532 nm output was obtained with a 3x3x5 mm^3 intracavity KTP. Fig. 1 shows the scheme for compact design of diode-pumped green laser.

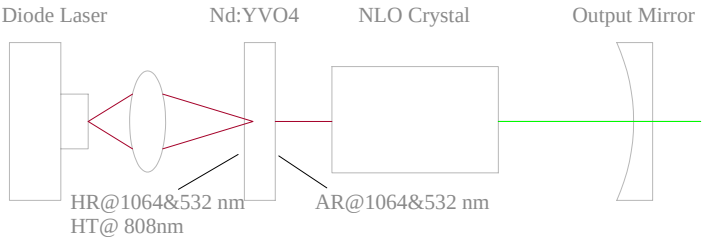


Fig. 1 Scheme for compact design of DPSS green laser with $Nd:YVO_4$

$Nd:YVO_4$ is efficient and has good performance in diode-pumped 1340 nm laser, due to its very large stimulated emission cross section at 1340 nm (over 18 times larger than that of Nd:YAG). If 1 mm long $Nd:YVO_4$ crystal pumped by an 1000 mW diode laser at 809 nm, 70 mW output at 1340 nm has been obtained.

More than 420 mW blue laser @ 457 nm based on $Nd:YVO_4$+ BBO crystals, is commercial available .

Standard Specifications

Nd concentrations Range	0.27at%, 0.5at%, 1.0at%, 2.0at%, 3.0at%
Wavefront Distortion	< λ/8 @633 nm
Scattering Sites	Invisible, probed with a Green laser
Orientation	A-axis or C-axis cut, ± 0.2°
Typical End-faces	1) Plano/Plano 2) Plano/Brewster-cut 3) Brewster-cut/Brewster-cut 4) Other angle-wedge
Surface Finish	10/5 scratch/dig as per MIL-O-13830A
Flatness	λ/10 @632.8 nm
Parallelism	< 10 arc seconds
Perpendicularity	< 5 arc minutes
Clear Aperture	> Central 90%
Coatings	1) S1 - HR @1064 nm & HT @808 nm (I*) S2 - AR @ 1064 nm 2) S1 - HR @1064 & 532 nm & HT @808 nm (II*) S2 - AR @ 1064 & 532 nm 3) S1 - AR @1064 nm & HT @808 nm(III*) S2 - AR @ 1064 nm 4) Both ends AR @1064 nm (IV*) 5) Other kinds of AR, HR coatings upon requests

*I) R_{1064nm} > 99.8%, T_{808nm} >95%

*II) R_{1064nm} > 99.8%, R_{532nm} > 99.5%, T_{808nm} > 95%

*III) R_{1064nm} < 0.2%, R_{808nm} < 0.4%

*IV) R_{1064nm} < 0.15%, per surface

$Nd:YVO_4$ Standard Products

Part No.	Nd Doping	Dimension	Coatings
NdYVO1301	1 at%	3x3x1mm	HR/AR Coating
NdYVO1305	1 at%	3x3x5mm	AR/AR Coating
NdYVO2301	2 at%	3x3x1mm	HR/AR Coating
NdYVO2302	2 at%	3x3x5mm	AR/AR Coating
NdYVO5308	0.5 at%	3x3x8mm	AR/AR Coating
NdYVO5310	0.5 at%	3x3x10mm	AR/AR Coating

NdYVO7308	0.27 at%	3x3x8mm	AR/AR Coating
NdYVO7310	0.27 at%	3x3x10mm	AR/AR Coating
NdYVO7312	0.27 at%	3x3x12mm	AR/AR Coating

Note

- Other specifications of Nd:YVO_4 crystals and coatings are available upon request.
- AOTK provides the complete diode pumped laser kits, including laser crystals (Nd:YVO_4, Nd:$GdVO_4$, and Nd:YAG), NLO crystals (KTP, LBO, BBO) and laser optics. Please refer to the information about diode pumped laser optics kits.

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