Introduction

This study give a comparison of the physical and optical properties of different crystalline active media used in laser applications. The principal object of these analysis concerns the identification of the dopant/host combination as well as composition (crystalline, ceramic) in order to satisfy the request of ESA in the ESA ITT AO/1-4691/04/NL/CP project. The relevant aspect analysed of these materials, give a balance of relevant characteristics that permits to consider the space related problems in their use. These aspects concern the principal physical properties of the host material (thermal conductivity, thermal expansion coefficient, density etc.), and the optical behavior of the dopant elements. Other important subject concerns the state of art of potentials and pumping scheme used to obtain laser emission with these active media.

1. A comparative analysis between different active materials doped with RE^{3+} ions.

1.1. Nd^{3+} doped host materials

1.1.1. Nd:YVO

Yttrium othovanadate (YVO_4) host crystals have a good optical properties concerning the possibility of its use as host material for active medium. This material, doped with RE ions such as Nd^{3+}, shows several advantages in laser applications where high power is required. Nd:YVO has a zircon-type structure with space group $I4_1/amd$ (D^{19}_{4h}) in the tetragonal system. The lattice constants are $a = b = 0.7123$ Å and $c = 0.6292$ Å at room temperature. The unit cell is composed by four YVO configurations. If the origin is chosen at the center of symmetry, the yttrium atoms (or the substitutional neodymium) are in *4a* Wyckoff position, the vanadium atoms in *4b*, and the oxygen atoms in *16h*. There are four V-O tetrahedral configurations, each having four oxygen-ion neighbors at the V-O distance of 0.1706 nm. The atoms in *4a* site are eight coordinated and in a unit cell there are four Y/Nd-O dodecahedral, each having four nearest oxygen-ions neighbors at Y/Nd-O distance of 0.2299 nm and four next-nearest oxygen-ions neighbors at Y/Nd-O distance of 0.2443 nm. The structural configuration of the unit cell makes the Nd:YVO an uniaxial crystal with refractive indices n_o=1.958 and n_e= 2.168 at 1064 nm [1]. A typical laser rod is oriented with the rod axis along an *a*-axis of the crystal ([100] orientation). Maximum absorption of pump light occurs for polarization along the *c*-axis. Some physical properties of Nd:YVO are reported in Table I [2][3].

$Nd:YVO_4$ physical properties	
Thermal expansion coef., α (10^{-6} K^{-1})	$\alpha_a = 4.43$ $\alpha_c = 11.4$
Thermal conductivity, K ($W \cdot m^{-1} \cdot K^{-1}$)	$K_{//} = 5.23$ $K_{\perp} = 5.10$
dn/dT (10^{-6} K^{-1})	(100) and (010) = 8.5 (001) = 3
Melting point (°C)	1825
Density (g/cm^3)	4.22
Mohs hardness	~ 5

Table I: *Nd:YVO physical properties*

The principal lasing wavelength of Nd:YVO_4 are centred at 914nm, 1064 nm and 1342 nm. The energy levels of Nd^{3+} ions in YVO_4 host are reported in fig. 1 [4]. All the lasing wavelength start form the $^4F_{3/2}$ level while the principal pumping level corresponds to the $^4F_{5/2}$ (809 nm pumped).

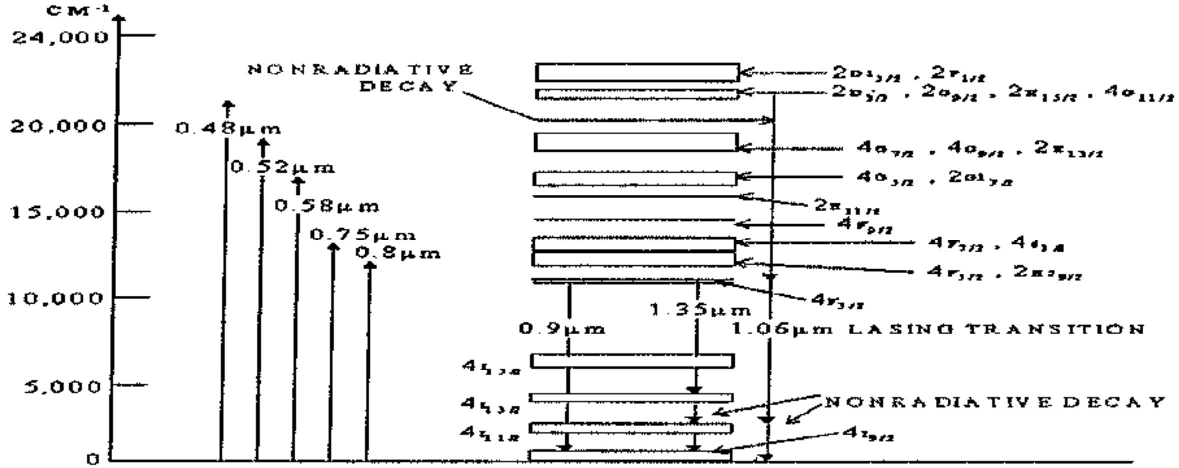

Fig.1: *Nd:YVO energy levels*

Figure 2 shows the absorption curve of 3 at.% Nd: doped YVO. The principal absorption bans are centred at 600 nm and 808 nm.

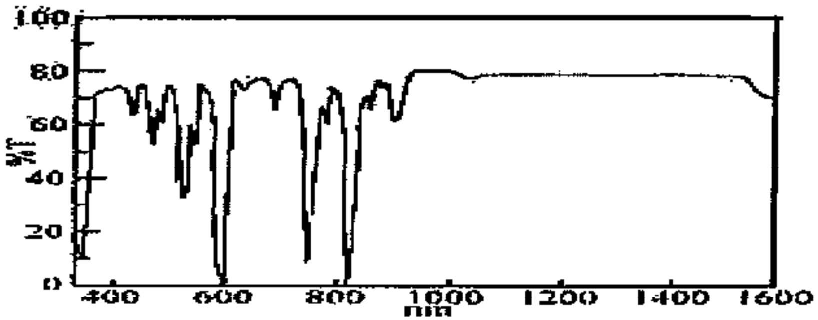

Fig.2: *Nd:YVO absorption*

Figure 3 shows the normalized fluorescence spectra from 800 nm to 1600 nm of Nd 1.1 at. % doped Nd:YVO4 for π polarization (a) and for σ polarization (b).

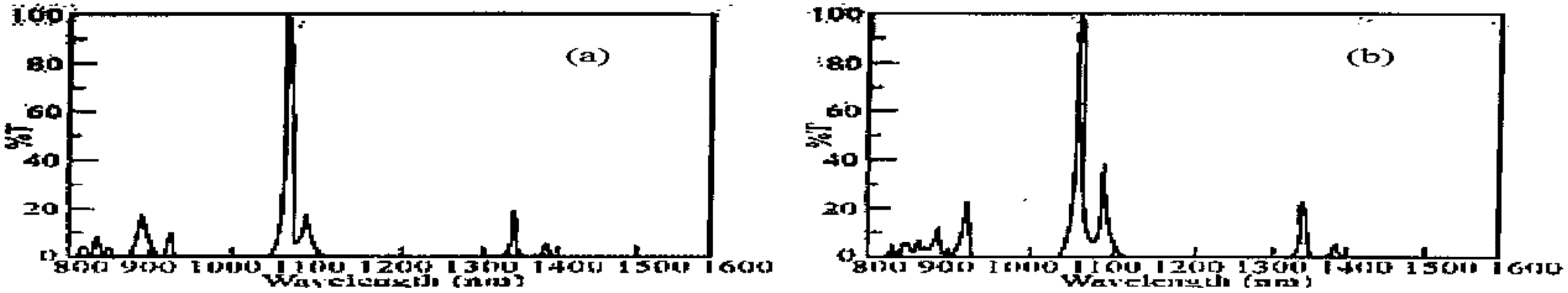

Fig.3: *Nd:YVO emission. (a) π polarization; (b) σ polarization*

Wang et al. analyses the optical properties of LD end-pumped $Nd:YVO_4$ crystals with various doping levels and length [5]. They investigate the absorption efficiency at π and σ direction for 1, 2, 3 and 5 at. % of Nd^{3+} ions in the melt. These concentration correspond respectively to 0.64, 1.22, 1.89, 3.15 at % of neodymium concentration in the crystal. Table II report the experimental results obtained for the absorption properties of Nd:YVO. The pump central wavelength is 809 nm that corresponds to the higher absorption peak of this material.

Nd^{3+} % at. (in melt)	Nd^{3+} % at. (in crystal)	Size	Absorption efficiency (%) in π direction	Absorption efficiency (%) in σ direction
1	0.64	3×3×1	76	63
1	0.64	3×3×3	87	81
1	0.64	3×3×5	93	89
2	1.22	3×3×1	81	69
2	1.22	3×3×2	93	82
2	1.22	3×3×3	93	86
2	1.22	3×3×4	93	88
3	1.89	3×3×1	86	74
3	1.89	3×3×2	96	90
3	1.89	3×3×3	96	94
3	1.89	3×3×5	96	96
5	3.15	3×3×1	97	90
5	3.15	3×3×5	97	97

Table II: *experimental results obtained by Wang [5]*

In this work, the effective stimulated emission cross-section of these different doping level are calculated with measured upper-level lifetimes. All samples have an 1064 nm HR coating and 809 nm AR coating on the pump end face, while the other end face is coated with 1064 nm AR coating. The crystals are pumped in π direction, favourable condition to obtain the maximum absorption of pump light.

The experimental setup of laser experiments is explained in detail by Wang. Figures 4(a-d) show the 1064 nm output power versus pump power of 1,2,3 and 5 at % crystals with various length. Table III shows the experimental results of this measure.