Nd^{3+} ACTIVATED OXIDE NONLINEAR LASER CRYSTALS IN THE GREEN

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In this work, nonlinear crystals are investigated as future diode pumped host laser materials in the green. Optical properties (absorption, emission, second harmonic generation, and continuous wave laser oscillation in the green) of the most relevant neodymium activated oxide laser crystals ($LiNbO_3$:MgO, $YAl(BO_3)_4$ and $LaBGeO_5$) are investigated and compared under similar experimental conditions.

1. INTRODUCTION

The use of nonlinear crystals doped with optically active ions was strongly supported after the demonstration continuos wave (cw) laser oscillation in $LiNbO_3$:MgO:Nd[1] under diode pumping. The combination of the excellent gain properties of the Nd^{3+} ion and the nonlinear properties of $LiNbO_3$ leads to a compact diode pumped solid state laser in the visible (546 nm) by self frequency doubling the laser line at 1092 nm, so that use of external nonlinear crystals is eliminated. However, in order to substantially reduce the optically induced damage due to the refractive index variations (photorefractive damage), a percentage of an additional codopant oxide (MgO, ZnO or Sc_2O_3)[2] must be incorporated during the crystal growth. Unfortunately, the codoping effect reduces the optical quality of crystals as well as the segregation coefficient for the Nd^{3+} ions.

This has supported research on other nonlinear host crystals for the Nd^{3+} ions[3-8] as well as alternative ways of eliminating the laser damage in $LiNbO_3$ while solving the former problems[9]. This type of lasers, based in nonlinear crystal, are usually referred to as self frequency doubling (SFD) lasers and have a variety of potential applications, such as high density data storage, laser printers, high brightness displays, medicine, undersea inspections, ...etc

In this work we analyze the optical properties of the neodymium doped SFD laser crystals which have been discovered until now. Particular emphasis has been given to $LiNbO_3$: MgO (LN:MgO), $YAl(BO_3)_4$ (YAB) and $LaBGeO_5$ (LBG) , crystals, which are available in our laboratory and therefore can be characterized under the same experimental conditions.

RESULTS AND DISCUSSION

Up to date, five Nd^{3+} doped oxide crystals have been demonstrated as SFD lasers, the three trigonal crystals mentioned above[1, 3-5], an orthorhombic crystal β′- $Gd_2(MoO_4)_3$ (GM)[6] and a monoclinic crystal $Ca_4GdO(BO_3)_3$ (CGB)[7]. Some important characteristics (crystal symmetry, non linear effective coefficient d_{eff}, laser wavelength λ_{laser}, type I phase matching angle with the optical axis θ_{PM} - angle where the refractive indices $n_{o,e}(\lambda) = n_{e,o}(\lambda/2)$, being the subscripts e = extraordinary and o= ordinary - and growth method) of these crystals appear listed in table 1.

Crystal	Space group	d_{eff} (pm/V)	λ_{laser} (nm)	θ_{PM} (°)	Growth Method	Ref.
LN:MgO	R_{3c}	5.3	1092	81.2	Czoch.	(1, 8)
YAB	D_3^7	1.9	1062	30.2	flux	(3, 4, 8)
LBG	C_3^2	0.3	1049	54	Czoch.	(5)
GM	C_{2v}^8	1.9	1060	60	Czoch.	(6)
CGB	C_m	0.7	1060	_	Czoch.	(7)

Table 1.- Characteristics of SFD laser crystals. GM and CGB are biaxial crystals. The pulling Czochralski method is abbreviated by "Czoch.".

Laser elements of LN:MgO:Nd (0.2%) , YAB:Nd (5.6%) and LBG:Nd (1.4%) were cut from the growth crystals with its maximum dimension (4 mm, 5 mm and 4 mm respectively) along the type I phase matching (PM) direction (see table 1) to investigate their optical spectroscopy (absorption and emission). Finally these crystals were located in the laser cavity described in reference 8, to produce laser green radiation by SFD and to determine the internal losses of the laser elements. All experiments were performed at room temperature.

Absorption spectra were taken for two polarizations; ordinary (electric field perpendicular to both c-optical axis and PM axis) and extraordinary (perpendicular to the ordinary polarization) to determine the most appropriate diode wavelength for each crystal. Considering the birefringence sign (positive or negative) of each crystal the optimum pumping wavelengths (combining low quantum defect and high absorption coefficient) are: 807.5 nm for LN, 807.3 nm for YAB (which are free from walk-off) and 798.4 nm for LBG .

Then, the polarized (extraordinary and ordinary) emission spectra of our PM cut laser crystals were systematically investigated in the wavelength range corresponding to the main laser channel, $^4F_{3/2} \rightarrow {}^4I_{11/2}$. As LN and YAB are crystals with negative birefringence the fundamental wave (FW) useful for SDF must be ordinary while for LBG (which is negative) the FW must be extraordinary. Thus these lasers operate at the peak infrared wavelengths related to these polarization states (1092 nm for LN:MgO, 1062 nm for YAB and 1049 nm for LBG), then giving green radiation at 546 nm (LN:MgO), 531 nm (YAB) and 524.5 nm (LBG).

Detailed absorption spectra have been also recorded around these FW and SH wavelengths[8]. No significant absorption were observed except for the SH wavelengths of YAB and LBG, where weak absorption (from ground or excited states) can lead to a reduction in the SH generation efficiency.

From the laser experiments in the FW, the internal losses of our crystals were determined : 2.7% for LN:MgO:Nd, 1.1% for YAB:Nd and 0.9 %for LBG:Nd [8]. Pump thresholds of order a few mW and slope efficiencies from 30-50 % were obtained for these crsytals.

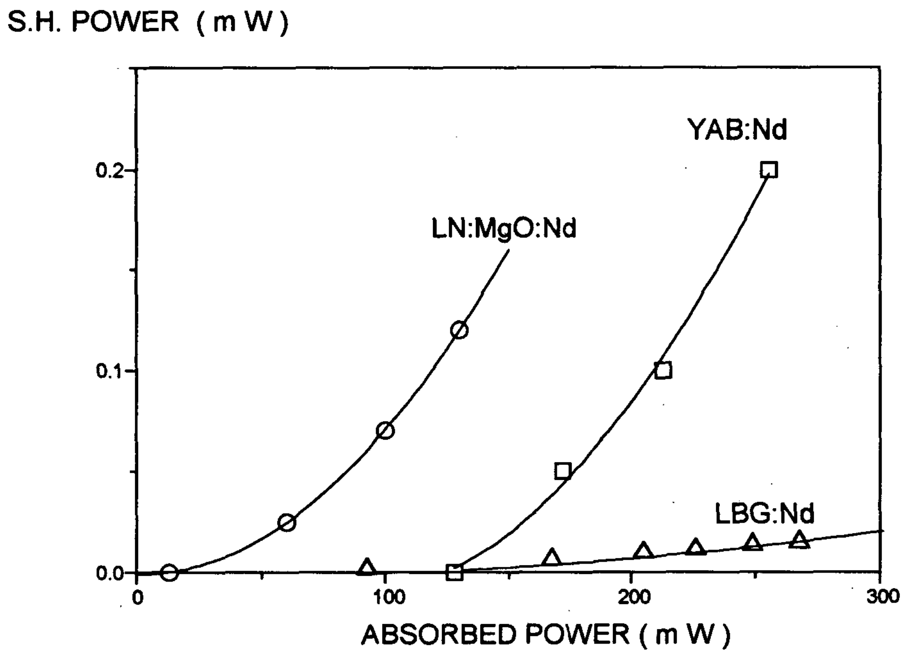

Figure 1.- SH power versus absorbed power curves.

Figure 1 shows, for comparison, the SH power versus absorbed power curves obtained with our PM crystals . In each case the cavity length and focusing system were suited to obtain maximum SH efficiency. Although the efficiencies obtained could be still increased (for instance using antireflection coatings in our crystals and using more adequate mirrors) it can be seen how LN:MgO:Nd is the most efficient system at low absorbed powers in accordance with its highest effective nonlinear coefficient (see table 1). However, due to the low Nd content, only a maximum absorbed power of 130 mW could be reached with about 0.1% of efficiency. The highest SH efficiency (0.7%) was obtained with our YAB:Nd at 725 mW of absorbed pump power, so that this system seems to be the most promising SFD laser. In fact a conversion efficiency of infrared pump power as high as a 20% has been recently demonstrated at 2.2 W of Ti-sapphire power[3].

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