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Investigation of LNA lasers operating in high average power

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Abstract: We have investigated the repetitive pulse laser properties of lanthanum neodymium magnesium hexaaluminate (LNA) single crystal. 86.6W average output power were obtained with slope efficiency of 2.5%, where a LNA crystal rod with 6mm diameter × 116mm long was pumped by flashlamp at high repetition condition.

Key words: LNA crystal solid-state laser thermal lensing

高平均功率 LNA 激光器研究

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摘要:给出了铝酸镁镧(LNA)激光晶体在重频脉冲运转下的激光特性,一根 i 6mm× 116mm 的 LNA 晶体在脉冲氙灯泵浦下,采用高重频脉冲工作方式,激光平均输出功率达到 86.6W,斜效率 2.5%。

关键词:LNA 晶体 固体激光器 热透镜

iv. Introduction

The physical and optical properties of lanthanum neodymium magnesium hexaaluminate (LNA) single crystal has been suggested that it may be a promising lasing material for high power laser applications. LNA is a optically uniaxial, congruently melting compound. The distribution coefficient for neodymium is near unity, and the concentration quenching of Nd^{3+} luminescences is relatively weak. This permits it to be doped with high concentration of neodymium without substantial reduction of fluorescence lifetime, while maintaining high optical quality. Considerable development of this material, in the areas of crystal growth, spectroscopy, physical property characterization, and laser physics has already taken place[1~3]. However, LNA laser suffers from thermal lensing effect, owing to the large rate of change of the index with temperature when pumped by a flashlamp in rod gemetry. This effect severely limit the performance of the laser when operated at high input power[4]. In this paper we present the results of an extensive investigation about high repetitive pulse performance of LNA lasers. This study has led to the development of a LNA laser device with an average output power of 86.8W and slope efficiency of 2.5%. So far to our knowledge these are the highest values reported for LNA crystal lasers.

㈦. The characteristics of LNA crystal

In general, LNA single crystals were grown along the orientation perpendicular to the crystalline c axis using Czochralski technique. The earlier work demonstrated that a LNA laser had an efficiency and threshold comparable to Nd: YAG laser. Laser action of LNA has been observed with pulsed and CW operation. Known spectroscopic and lasing properties of LNA were summarized in reference[3]. Table shows a compilation of the physical properties of LNA, Nd: YAG, Nd: YLF and Nd: glass which are relevant to laser design and performance.

Table　Comparative properties of several Nd^{3+} laser host materials

property	Nd: glass	Nd YAG	Nd: YLF	LNA
optical property	isotropic	isotropic	uniaxial	uniaxial
index	1.56	1.83	1.45	1.77
melting point(℃)	N/A	1970	900	1870
fluorescent lifetime(μs)	~100	230	520	260
total cross-section($10^{-19}cm^2$)	0.1~0.4	4.0	2.0~3.0	0.7
thermal conductivity(W/m℃)	~1	~13	~5	~14
expansion coef. (10^{-6}/℃)	~10	7.5	~8	~10
dn/dt (10^{-6}/℃)	−6.8~8.6	7.3	—	18

From above table, we can see that dn/dt of LNA is more two times than Nd: YAG. The large rate of change of the index with temperature for LNA is due to its anisotropy of thermal expansion and thermal conductivity.

㈣ Thermal lensing

LNA lasers have been fabricated in a rod geometry. Like other solid-state lasers, LNA rod manifests thermal lensing effect under thermal loading. This effect severely degrade the performance of LNA laser systems at medium pump power and completely extinguish laser action at high pump power. Clearly the reduction thermal lensig effect is essential to the development of high average power LNA laser devices. Thermal lens formation in laser rods arises from the combined effects of the thermal-optic, stress-optic and elastic responses of the material to the temperature and stress fields resulting from thermal loading. An expression for the thermal focusing length f in a cylindrical laser rod is:[5]

$$f^{-1} = \frac{P}{KA}\left[\frac{1}{2}\frac{dn}{dt} + \alpha c n^3 + \frac{2r(n-1)}{L}\right]$$

where K is thermal conductivity, A is cross section area of the rod, P is the heat dissipated in the rod, α is the thermal expansion coefficient, n is the refractive index, r is the rod radius, L is the rod length, and c is a measure of the stress-optic effect. The last term, arising from rod end elastic distortions, can be made negligibly small by mounting the rod without pumping the ends. Generally, of the remaining two terms, the dn/dt contribution is larger by about an order of

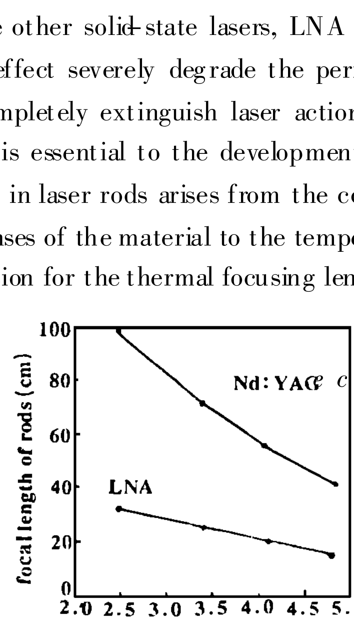

Fig. 1　Thermal focal length of rods as a function of pump power

magnitude than the stress-optic contribution. So dn/dt is the dominant contribution to thermal lensing effect, and LNA lasers exhibit limited power capabilities. We undertook a preliminary experimental investigation of geometry thermal lensing for LNA. rod for this, a He-Ne (λ= 632.8nm) laser probe beam was used to measure the focal length of LNA laser rod as a function of flashlamp power. Average pump powers in range of 1~ 5kW were used. The result is shown in Figure 1. For comparison, we also measured the focal length of Nd: YAG laser rod as a function of input power. Becauese LNA has shorter focal length than Nd: YAG, as shown in Figure 1, focusing for LNA laser rod is much greater than Nd: YAG.

㈤. The operation of lasers

The high average power LNA lasers were investigated using a series of the LNA rods with φ6mm × 116mm long oriented along c axis. The rod end faces with antireflection coat provide reflectivity below 0.2% at 1.054μm. The laser experiments were performed in a double ellipse pump chamber. The LNA rods were pumped by two Xe-flashlamps. The laser pump chamber was shielded with a filter tube to avoid the excessive thermal load due to the ultra-violet light from the flashlamp. A laser resonator was formed, in which pump-induced lensing of rod was taken into account. The laser has been tested at free-running repetitive pulsed state. The input-output characteristics were measured by varying the repetition rate from 1Hz to 40Hz. The output coupler reflectivity was 40 percent. The average output power as a function of input power is shown in Figure 2. The optical output power of 86.8W and the slope efficiency of 2.5% were botained. The electrical-to-optical overall efficiency is 1.8%. No tendency of saturation of the output laser power was observed.

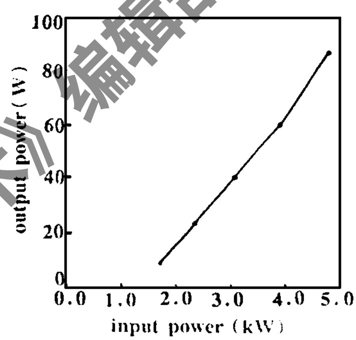

Fig. 2 Measured average output power as a function of input pump power

㈨. Conclusions

Something about the performances of LNA lasers operated in high average power have been described We have found that a first-orer compensation of the LNA thermal lensing can be achieved by thermal compensated resonator. Considerable improvement should be possible by design zig-zag slab geometry LNA lasers or by diode pump. In spite of the serious thermal lensing, LNA crystal is a promising condidate for high average power operation because of its greater Nd concentration.

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