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Characterization of Diode Laser-Pumped Nd:YVO_4 Disk Laser

In this work describe experimental set up disk laser of Nd:YVO_4 in active mirror configuration, face pumping and cooling by thermoelectric Cooler (TEC) type heat exchanger to over come the limitation of prior design. With (4x5x1mm) disk dimensions to investigate the relationship between the pumping power from a diode laser at (808nm) with the optical elements in the setup and with the output power. The results show that a (0-600)mW CW output power which indicate 56% efficiency at (1064nm) wavelength from Nd:YVO_4 thin disk material when pumped with power between (0-1500) mW from a 808nm CW laser diode.

Keywords: Solid-state lasers, Active mirror, Nd:YVO_4 laser, Beam quality
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1. Introduction

Disk-type solid-state laser (SSL) has been recognized for its inherently low susceptibility to thermo-optical distortions, thermal lensing and stress birefringence [1]. Its large, round aperture reduces diffraction and beam clipping losses experienced by other SSL configurations. These attributes make the disk laser an attractive candidate for high-efficiency systems producing good quality beams. This type of laser is the subject of this work. The idea was proposed by Giesen in 1994. The attempts to use disk configuration is began before that where the early work on what called active mirror by General Electric Co. in 1968, Bert et al in 1974 [2].

In 1978, comparison study between the slab and disk configuration in parasitic oscillation, absorption was published [3]. Time resolved spectroscopy of flash lamp pumping a disk amplifier is studied by John H. Kelly et al in 1980 [4]. In 1981 J. A. Abate et al using Nd:glass material as disk laser called active mirrors, they operate it in high repetition rate as ignition device for controlled fusion experiments [2] in the same year David C. Brown et al gave the performance of active mirror amplifier in staging of both short pulse and long pulse for Nd:glass material using different configurations (split, sandwich) [5] .Also in 1981 J.H. Kelly et al gives the theoretical discretion of pumping system of the active mirror amplifier using a computer program called INVDEN to predict the performance of such system [6]. Eggleston *et al* presented detailed theoretical description of all the thermal effects in the slab geometry laser at first and then calculated these effects through computer program for Nd:YAG then they with 5Hz was the first high average power operation using Nd:Glass active mirror amplifier it was presented by David C. Brown et al 1n 1986 [7]. In 1994 Giesen et al opened the door for new configuration in the solid state laser called "the thin disk laser "to reach a high average power solid state laser pumped by diode array (HAP DPSSL) [3]. Lawrence Livermore National Laboratory (LLNL) and Boeing company through John Vetrovec and others published many papers in using and development this type of laser from 1997 to 2004 [8-28].

2. Laser Set-up

The schematic layout of the face pumped Nd:YVO_4 laser with a fiber-coupled diode laser is shown in Fig. (1). The laser diode driver “model *LDD1-1T-D*" has Thermo-Electric Controller and LCD display used to operate the laser diode unit with CW mode as shown in Fig. (2). Thermistors are useful for measuring temperature and gas flow or wind velocity. The laser diode is an 808nm, 2W laser diode with Single longitudinal mode Low threshold current 450mA. The optical fiber cable is diameter coupled to the laser diode .Optical and Electrical Characteristics of the laser diode is listed in the Table (1).

A two face dichroic mirror is used in the system. The first face mirror is high transparence for 808nm; the second face is anti reflection for 808nm high reflection for 1064nm at 45°.The crystal is of Nd:YVO_4 with (0.3at.%) doped with (4x5x1) mm dimensions placed on indium material of 0.1 mm thickness. In front of the disc is Al plate, and behind it there is a Cu plate those plates used as heat sink and 90% reflected mirror at 1064nm with ROC (200 mm).

Table (1) The optical and electrical characteristic of the laser diode

Parameter	Symbol	Min.	TYP.	Max.	Unit	Test Condition
Peak Wavelength	λ_p	805	808	811	nm	P=2W
Beam Divergence	$\Theta_{\parallel}$	6	8	10	Deg	FWHM
Beam Divergence	$\Theta_{\perp}$	12	16	20	Deg	FWHM
Operating Voltage	V_f		2.0	2.4	V	P=2W
Threshold Current	I_{th}		450	470	mA	CW
Operation Current	Iop		1.9	2	A	P=2W
Optical Output Power	P_0	2	Rating		W	
Case Temperature	T_0	12 - 35	Rating		°C	

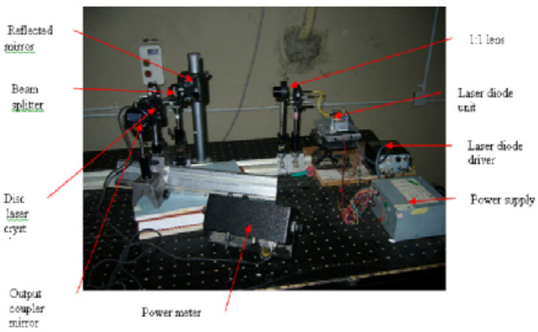

Fig. (1) Experimental setup of the diode pumped disc laser

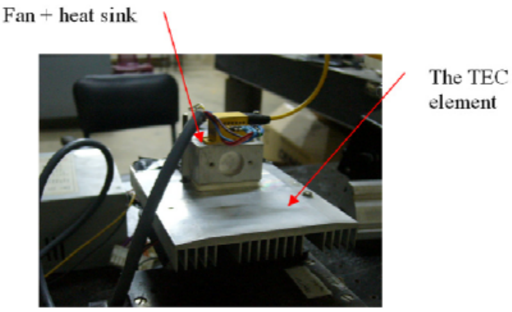

Fig. (2) The TEC element with laser diode. *Unit*

The beam radiated with 808nm from the laser diode is passed from the lens to focus on the disc crystal through the beam splitter. Laser beam of 1064nm, which radiated from the crystal is incident on the beam splitter then reflected on the output coupler mirror. A narrow band filter for 1064nm is used to test the output from the disc. An IR to visible converter is used to track the spot of laser in each point.

Fig (3) the schematic layout of the diode pumped Nd:YVO_4 laser with fiber coupled and presents the ray direction in the setup, where the lens on the disc crystal passing through the beam splitter focuses the laser from the diode, some of these rays are reflected out from the first surface so a high-reflected mirror is used to redirect that rays to the beam splitter and then to the disc. The output laser at 1064nm from the disc is reflected by high reflection surface of the rear face of the disc beam splitter towered the output coupler mirror. The out put beam at 1064nm is checked using a narrow band filter.

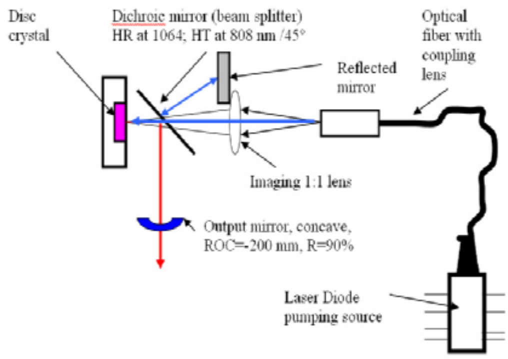

Fig. (3) The ray direction of the system

3. Experimental Results

A 2W laser diode with threshold of 325mA was used. The experimental curve of current-output of the laser diode is shown in Fig. (4). A GENETC power meter model (CE TPM 300, SP-310WB) is used to measure the out put power where it is placed 3cm away from the optical fiber because of the large divergence angle of the laser after the fiber.

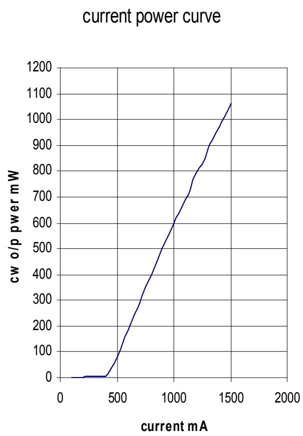

Fig. (4) Experimental calibration results

The results of the measuring power at each step in the set up in Fig. (3) as shown in Table (2) and can summarizes the following

- The threshold current is about 350mW

- The power of the laser diode decreases with about 8% this was found by dividing the value of the power before and after the lens.
- We found that there are some reflected beams from the beam splitter because the inaccuracy in determining the (45 degree) angle which is required for the beam splitter, so we used a reflected mirror to redirect this reflected beam to the beam splitter .The effects of the reflected mirror can be shown in Fig. (5)
- The whole optical loss from the lens to the laser disc crystal is about 0.72%. This is shown in Fig. (6)
- The CW output power from the disc is (600mW) and the optical efficiency is about 56% this is calculated by taken the slope between the absorbed powers after the beam splitter to the out put power after the out put coupler mirror as shown in Fig. (7)

Table (2) the results of the measuring power at each step in the setup

Current (mA)	Direct (mW)	Corrections Factor	After lens	Power after beam splitter without reflected mirror	Power after beam splitter with reflected mirror	O/P Power without Reflected Mirror	O/P Power with Reflected Mirror
100	0	0	0	0	0	0	0
150	2	2.857143	2.285714	1.782857	2.057143	0.980571	1.131429
200	2	2.857143	2.285714	1.782857	2.057143	0.980571	1.131429
250	4	5.714286	4.571429	3.565714	4.114286	1.961143	2.262857
300	4	5.714286	4.571429	3.565714	4.114286	1.961143	2.262857
350	4	5.714286	4.571429	3.565714	4.114286	1.961143	2.262857
400	5	7.142857	5.714286	4.457143	5.142857	2.451429	2.828571
450	36	51.42857	41.14286	32.09143	37.02857	17.65029	20.36571
500	82	117.1429	93.71429	73.09714	84.34286	40.20343	46.38857
550	136	194.2857	155.4286	121.2343	139.8857	66.67886	76.93714
600	185	264.2857	211.4286	164.9143	190.2857	90.70286	104.6571
650	247	352.8571	282.2857	220.1829	254.0571	121.1006	139.7314
700	293	418.5714	334.8571	261.1886	301.3714	143.6537	165.7543
750	347	495.7143	396.5714	309.3257	356.9143	170.1291	196.3029
800	400	571.4286	457.1429	356.5714	411.4286	196.1143	226.2857
850	450	642.8571	514.2857	401.1429	462.8571	220.6286	254.5714
900	498	711.4286	569.1429	443.9314	512.2286	244.1623	281.7257
950	550	785.7143	628.5714	490.2857	565.7143	269.6571	311.1429
1000	595	850	680	530.4	612	291.72	336.6
1050	640	914.2857	731.4286	570.5143	658.2857	313.7829	362.0571
1100	688	982.8571	786.2857	613.3029	707.6571	337.3166	389.2114
1150	733	1047.143	837.7143	653.4171	753.9429	359.3794	414.6686
1200	790	1128.571	902.8571	704.2286	812.5714	387.3257	446.9143
1250	825	1178.571	942.8571	735.4286	848.5714	404.4857	466.7143
1300	885	1264.286	1011.429	788.9143	910.2857	433.9029	500.6571
1350	926	1322.857	1058.286	825.4629	952.4571	454.0046	523.8514
1400	972	1388.571	1110.857	866.4686	999.7714	476.5577	549.8743
1450	1010	1442.857	1154.286	900.3429	1038.857	495.1886	571.3714
1500	1060	1514.286	1211.429	944.9143	1090.286	519.7029	599.6571

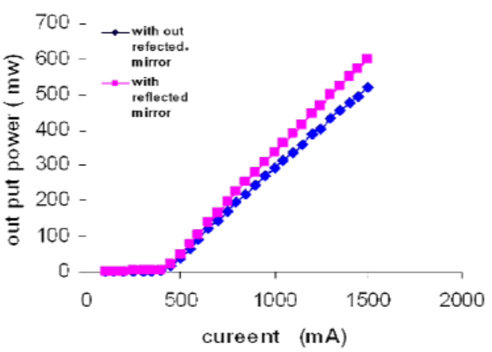

Fig. (5) The out put power V.S. current as a function the reflected mirror

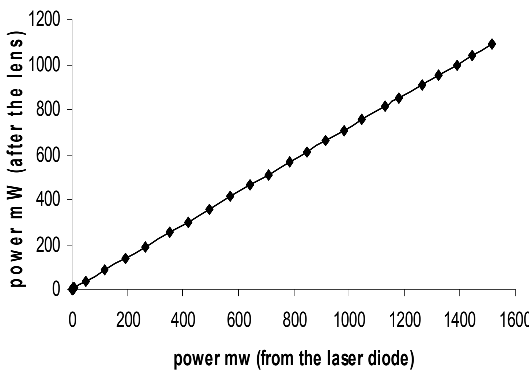

Fig. (6) Optical loss of the laser diode power

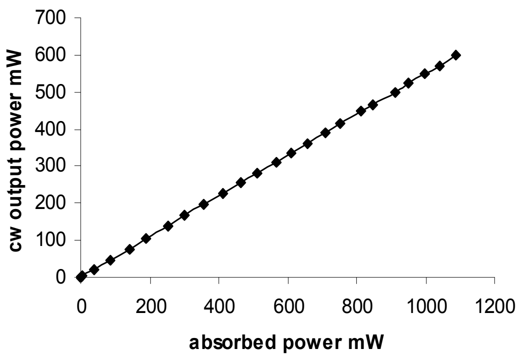

Fig. (7) The optical efficiency of the disc laser

4. Conclusion

For the experimental realization of the used disk laser of the present work an optical efficiency about 56% between the absorbed and output powers was achieved where a 600mW in CW operation was found.

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