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Characterization of diode laser pumped "Nd:YVO_4 Disk laser

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In this work describe experimental setup disk laser of Nd:YVO4 in an active mirror configuration, face pumping and cooling by Thermoelectric Cooler (TEC) type heat exchanger to overcome the limitation of the prior design. With (4x5x1mm) disk dimensions to investigate the relationship between the pumping power from a diode laser at (808 nm) with the optical elements in the setup and with the output power. The results show that a (0-600) mW CW output power which indicates 56% efficiency at (1064nm) wavelength from Nd: YVO4 thin disk material when pumped with power between (0-1500) mW from an 808nm CW laser diode.

Keywords: solid-state lasers; Active Mirror; Nd:YVO4 laser; Beam quality; diode laser.

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 A.Giesen in 1994. The attempts to use disk configuration is beginning before that where the early work on the what is called active mirror by General Electric Co. in 1968, Bert et al in 1974 [2]. In 1978 a comparisons study between the slab and disk configuration in parasitic oscillation, absorption is 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 the pumping system of the active mirror amplifier using a computer program called INVDEN to predict the performance of such system [6]. J.M.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 5 Hz 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 A. 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 developing this type of laser from 1997 to 2018 [8-28].

2. EXPERIMENTAL

2.1. Laser set-up

The schematic layout of the face-pumped Nd: YVO4 laser with a fiber-coupled diode laser . 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. 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).

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
Parameter	Symbol	Ratings				
Optical Output Power	P_0	2W				
Case Temperature	T_o	12 to +35ºC				

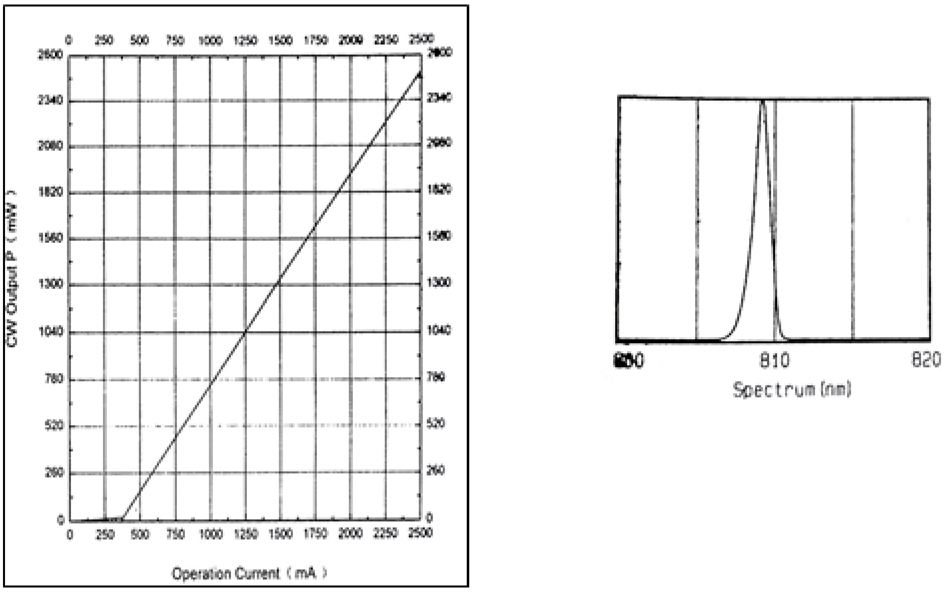

Figure 1 a) the current vs. output power of the diode, b) the spectral output of the diode

Figure (1 a, b) shows the current vs. output power of the diode and the right figureure shows the spectral output, the peak of the laser is at 808 nm.

A two-face dichroic mirror is used in the system. The first face mirror is high transparency for 808 mn; the second face is anti-reflection for 808 nm high reflection for 1064 nm at 45□.The crystal is of Nd: YVO4 with 0.3 at % 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 a heat sink and 90% reflected mirror at 1.06 □m with ROC (200 mm).

The beam radiated with 808 nm from the laser diode is passed from the lens to focus on the disc crystal through the beam splitter. A laser beam of 1.06 □m, which radiated from the crystal is incident on the beam splitter then reflected on the output coupler mirror. A narrow band filter for 1.06 nm is used to test the output from the disc. An I.R to the visible converter is used to track the spot of the laser in each point.

Figure (2) the schematic layout of the diode-pumped Nd:YVO4 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 1064 nm from the disc is reflected by the high reflection surface of the rear face of the disc beam splitter towered the output coupler mirror. The output beam at 1064nm is checked using a narrow band filter.

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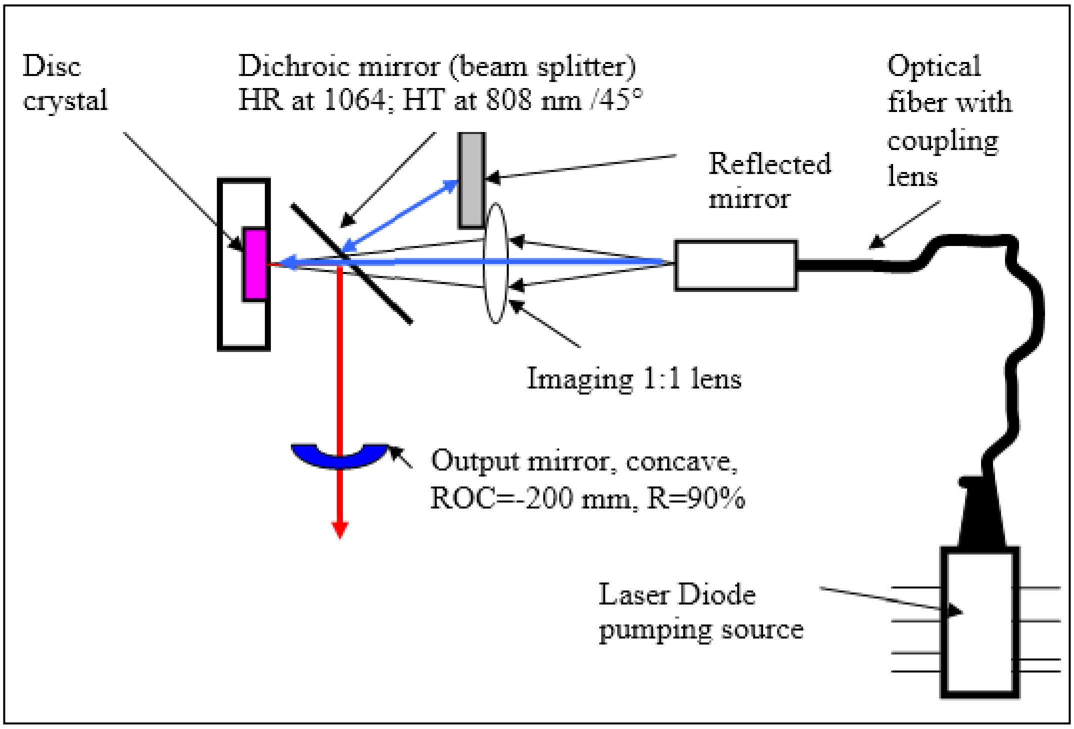
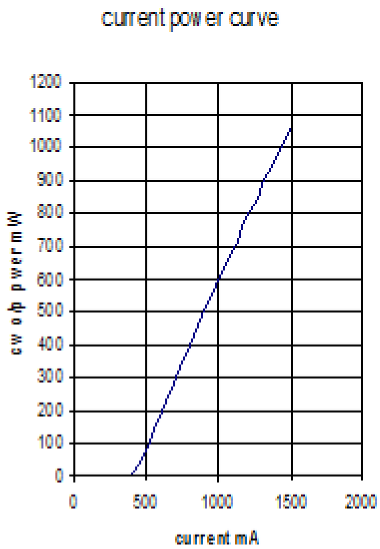


Figure 2 the ray direction of the system.

3. RESULTS AND DISCUSSION

3.1 Optical properties

A 2 W laser diode with a threshold of 325mA is used. The current to the out put curve for the laser diode can be shown in figures (3, 4).;



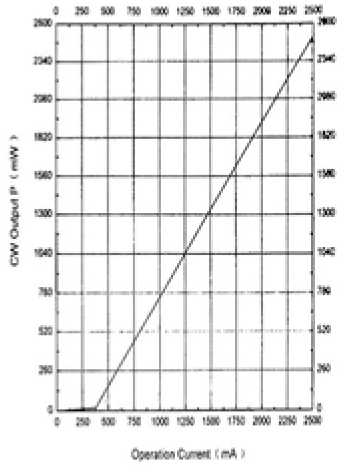


Figure (3) Experimental calibration Curve Figure (4) the company standard Results

Figure (3) shows our experimental calibration result and Figure. (4) Shows the company curve. The comparison between them one can find there a correction factor between them with 0.7. A GENETC power meter model (CE TPM 300, SP-310WB) is used to measure the output power where it is placed 3 cm away from the optical fiber because of the large divergence angle of the laser after the fiber.

The results of the measuring power at each step in the set up in figure (2) as shown in the table (2) and can summarizes the following

•The threshold current is about 350 mw 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 of the inaccuracy in determining the (45 degrees) angle which is required for the beam splitter, so we used a reflecting mirror to redirect this reflected beam to the beam splitter.The effects of the reflecting mirror can be shown in Figure. (5)

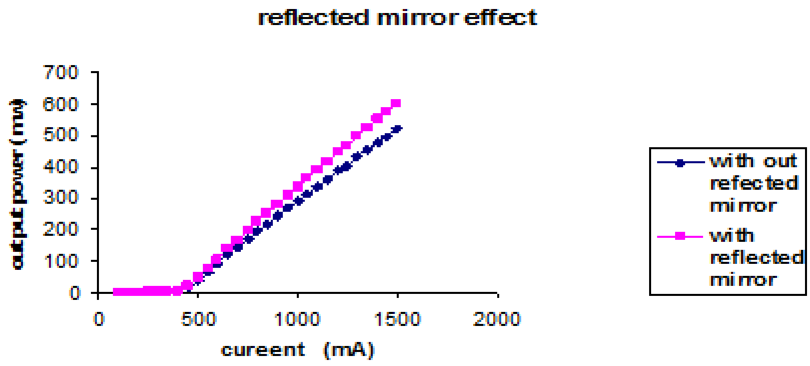


Figure. (5) The output power V.S. current as a function the reflected mirror.

- The whole optical loss from the lens to the laserdisc crystal is about 0.72%. This is shown in Figure. (6)

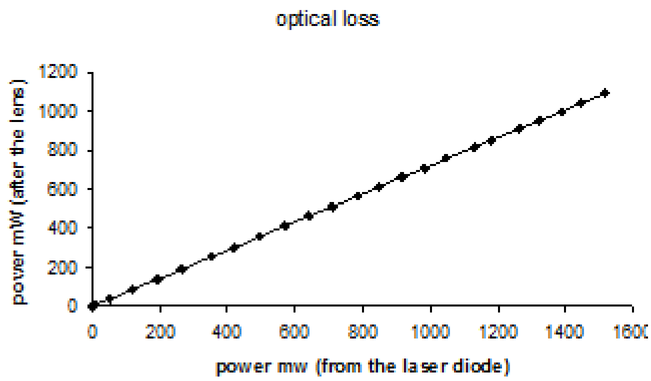


Figure 6 Optical loss of the laser diode power.

•The CW output power from the disc is (600 mw) and the optical efficiency is about 56% this is calculated by taking the slope between the absorbed powers after the beam splitter to the output power after the output coupler mirror as shown in Figure. (7).

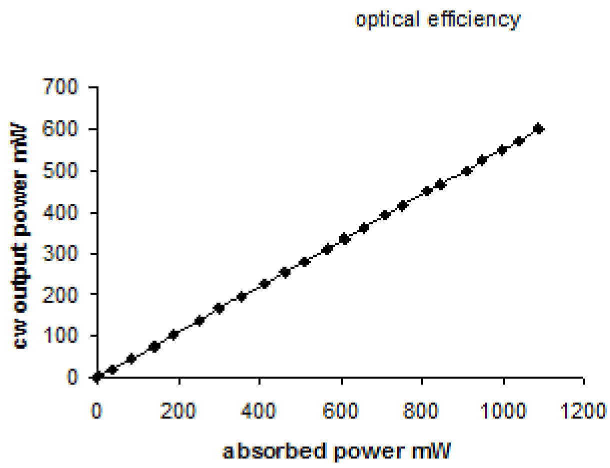


Figure 7 The optical efficiency of the disc laser.

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	2.28574	1.782857	2.057143	0.980571	1.131429
200	2	2.857143	2.28574	1.782857	2.057143	0.980571	1.131429
250	4	5.714286	4.57149	3.565714	4.114286	1.961143	2.262857
300	4	5.714286	4.57149	3.565714	4.114286	1.961143	2.262857
350	4	5.714286	4.57149	3.565714	4.114286	1.961143	2.262857
400	5	7.142857	5.71426	4.457143	5.142857	2.451429	2.828571
450	36	51.42857	41.1426	32.09143	37.02857	17.65029	20.36571
500	82	117.1429	93.7149	73.09714	84.34286	40.20343	46.38857
550	136	194.2857	155.426	121.2343	139.8857	66.67886	76.93714
600	185	264.2857	211.426	164.9143	190.2857	90.70286	104.6571
650	247	352.8571	282.287	220.1829	254.0571	121.1006	139.7314
700	293	418.5714	334.851	261.1886	301.3714	143.6537	165.7543
750	347	495.7143	396.574	309.3257	356.9143	170.1291	196.3029
800	400	571.4286	457.149	356.5714	411.4286	196.1143	226.2857

850	450	642.8571	514.287	401.1429	462.8571	220.6286	254.5714
900	498	711.4286	569.149	443.9314	512.2286	244.1623	281.7257
950	550	785.7143	628.574	490.2857	565.7143	269.6571	311.1429
1000	595	850	680	530.4	612	291.72	336.6
1050	640	914.2857	731.426	570.5143	658.2857	313.7829	362.0571
1100	688	982.8571	786.287	613.3029	707.6571	337.3166	389.2114
1150	733	1047.143	837.713	653.4171	753.9429	359.3794	414.6686
1200	790	1128.571	902.851	704.2286	812.5714	387.3257	446.9143
1250	825	1178.571	942.851	735.4286	848.5714	404.4857	466.7143
1300	885	1264.286	1011.49	788.9143	910.2857	433.9029	500.6571
1350	926	1322.857	1058.26	825.4629	952.4571	454.0046	523.8514
1400	972	1388.571	1110.87	866.4686	999.7714	476.5577	549.8743
1450	1010	1442.857	1154.26	900.3429	1038.857	495.1886	571.3714
1500	1060	1514.286	1211.49	944.9143	1090.286	519.7029	599.6571

4. CONCLUSIONS

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