DEVELOPMENT OF CW AND Q-SWITCHED DIODE PUMPED ND: YVO_4 LASER

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ABSTRACT

The development and parameter of continuous wave and Q-switched diode pumped Nd: YVO_4 laser is discussed. End pumping configuration has been used in this process. Suitable laser diode of wavelength 808nm was selected in accordance with the material chosen to obtain the required output. Resonator length and radius of curvature of mirror were selected to have a stable resonator cavity. Its power was observed to be 297mW at 834mW input power. The output power and peak intensity were stable over a period of operation. Passive Q-switch Cr^{4+}: YAG was used to obtain the Q-switch laser and its pulse width was recorded to be around 20-25 ns.

Keywords: Diode pumped, Nd: YVO_4 laser, Q-switch

I. INTRODUCTION

Diode-pumped solid-state (DPSS) lasers are gaining acceptance in industrial applications due to improved performance and reducing price. There is an expected growth rate of 24%, twice that of flash lamp-pumped solid-state lasers in the same period [1][2]. It is expected that DPSS lasers will continue to penetrate the flash lamp-pumped solid-state laser market at a rapid rate. Recently there has been great interest in the Nd: YVO_4 crystal as a lasing media. Neodymium-doped yttrium orthovanadate (often called just “vanadate”) has several spectroscopic properties that are particularly relevant to laser diode pumping. The two outstanding features are a large stimulated emission cross section that is five times higher than Nd: YAG, and a strong broadband absorption centered at 809 nm with a useful range (at 50% of the peak) of 801 to 821 nm [3]. The vanadate crystal is naturally birefringent. Nd: YVO_4 laser performance is more tolerant to diode temperature variations because of the large pump bandwidth. If one defines this bandwidth as the wavelength range where at least 75% of the pump radiation is absorbed in a 5 mm thick crystal, then one obtains for Nd:YVO_4 a value of 15.7 nm, and 2.5 nm for Nd: YAG [4]. Nd: YVO_4 crystal is selected over Nd: YAG as it has absorption coefficient three times and absorption bandwidth two times that of Nd: YAG crystal. It exhibits a much lower laser threshold compared to a similar size Nd: YAG crystal. This is due to the fact that the product of its lasing cross section and upper state lifetime is twice that of Nd: YAG [5]. Compared with Nd: YAG for diode laser pumping, Nd: YVO_4 lasers possess the advantages of lower dependency on pump wavelength and temperature control of a diode laser, wide absorption band, higher slope efficiency, lower lasing threshold and single-mode output. The properties of Nd: YVO_4 can best be exploited in an end-pumped configuration. In end pumped systems the pump beam is usually highly focused, and it is difficult to maintain a small beam waist over a distance of more than a few millimeters. In this case a material such as Nd: YVO_4, which has a high absorption coefficient combined with high gain, is very advantageous. Nd: YVO_4 is capable of highly efficient laser operation, high repetition rate Q-switching and intra-cavity frequency doubling. The diode laser-pumped Nd: YVO_4 compact laser and its frequency-doubled green, red or blue laser light will be the ideal laser tools of machining, material processing, spectroscopy, wafer inspection, light show, medical diagnostics, laser printing and the most widespread applications.

A mode of laser operation extensively employed for the generation of high pulse power is known as Q-switching. It has been so designated because the optical *Q* of the resonant cavity is altered when this technique is used. The quality factor *Q* is defined as the ratio of the energy stored in the cavity to the energy loss per cycle [6]. Consequently, the higher the quality factor, the lower the losses.

In the technique of Q-switching, energy is stored in the amplifying medium by optical pumping. Although the energy stored and the gain in the active medium are high, the cavity losses are also high, lasing action is prohibited, and the population inversion reaches a level far above the threshold for normal lasing action. When a high cavity *Q* is restored, the stored energy is suddenly released in the form of a very short pulse of light.

A passive Q-switch consists of an optical element, such as a cell filled with organic dye or a doped crystal, which has a transmission characteristic. The material becomes more transparent as the fluence increases, and at high fluence levels the material "saturates" or "bleaches," resulting in a high transmission. The most common material employed as a passive Q-switch is Cr^{4+}: YAG. The Cr^{4}+ ions provide the high absorption cross section of the laser wavelength and the YAG crystal provides the desirable chemical, thermal, and mechanical properties required for long life [7]. Cr^{4+}: YAG offers several significant advantages over active acousto-optic and electro-optic devices including elimination of high voltage power supply, improved reliability and reduced package size. Cr^{4+}: YAG is more robust than dyes or color centers and is the material of choice for Nd lasers. [8]

II. EXPERIMENTAL SETUP

The laser cavity consist of neodymium-doped yttrium vanadate crystal (3% Nd doping of dimensions 3x3x1 mm), a lens of 15 mm diameter (focal length: 25 mm) and a 100 mm radius of curvature output coupler. One face of the lens forms one end of the resonator and has been coated for high transmission at 808 nm pump wavelength. The lens focuses the pump beam so that high intensity beam was obtained. So to obtain high efficiency and better beam quality, the Nd: YVO_4 crystal was placed at the focus of the lens. One face of mirror has high reflection coating (reflectivity: 95%) at the laser wavelength of 1064 nm, which forms the other end of the resonator. A hemispherical cavity was designed in this experiment. Laser diode of wavelength 808 nm was used for pumping. RG 850 filter was used to filter out the output beam from the pump beam. Cr^{4+}: YAG passive Q-Switch was placed between the output coupler and Nd: YVO_4 crystal. The pumping scheme, together with the experimental setup, are shown in Fig. 1. The apparatus were fixed with the help ofmagnetic base and mounts. Laser diode, lens, crystal and mirror were aligned with respect to each other with the help of already aligned He-Ne Laser. The maximum available pump power incident on the crystal is ~3W.

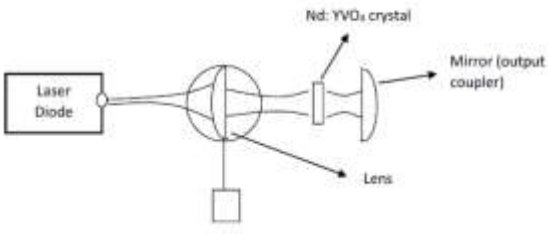

Fig 1: Layout of Experimental Setup

The stability of the resonator cavity depends on the resonator length, L and radius of curvature of the mirror (output coupler), R_1. It depends on two factors g_1 and g_2 [9].

$$g_1 = \left(1 - \frac{L}{R_1}\right), g_2 = \left(1 - \frac{L}{R_2}\right) \quad (1)$$

R_2 equals infinity ($g_2 = 1$) in our case since there was a hemispherical resonator. The cavity configuration is said to be stable if g_1 and g_2 correspond to points located in the area enclosed by branch of hyperbola $g_1g_2 = 1$ and the coordinate axis.

III. EXPERIMENTAL RESULTS

Fig. 2 shows the 3-D and 2-D profile of Nd: YVO_4 laser obtained using New Port LBP series beam profiler. The red color indicates the maximum intensity, which is at the center of the beam and as the intensity decreases, the color change from red to blue. This was obtained when all the components are properly aligned with respect to each other. The resonator length was observed to be ~65mm (0.065 m) for a near perfect beam. The wavelength of the laser was measured using wavelength spectrometer with the combination of filters so as to obtain maximum peak and was found out to be 1064 nm, which is represented in Fig. 3. The output power (measured with Ophir Nova II Power meter) of the laser at a constant input was observed to be consistent over the period of observation. The consistency can be seen in Fig. 4. Fig. 5 shows that the output power linearly varies with the input power. The laser was observed to have ~36% efficiency. The minimum pumping power necessary to produce an output was less than 0.22W, which is in conformity of the fact that Nd: YVO_4 has low lasing threshold.

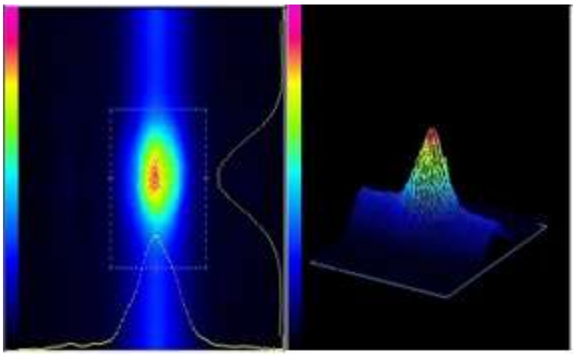

Fig.2 : 2-D (left) & 3-D (right) profile of Nd: YVO_4 laser

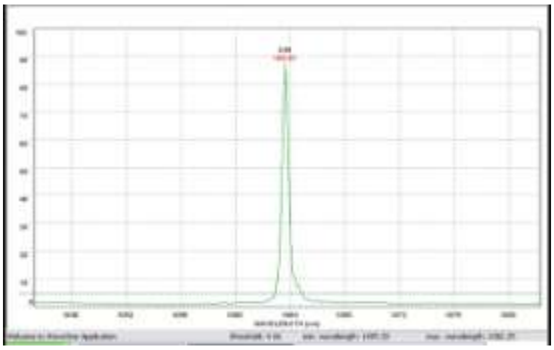

Fig 3: Wavelength of output laser

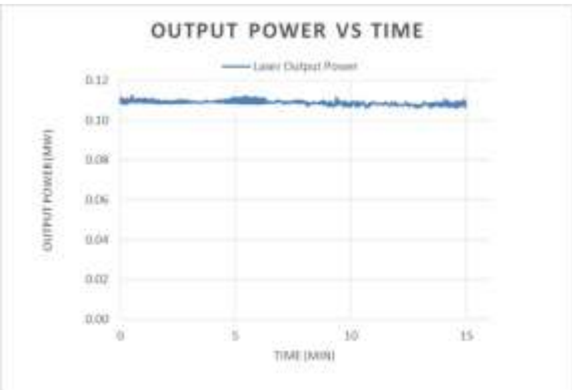

Fig 4: Consistency of Output Power

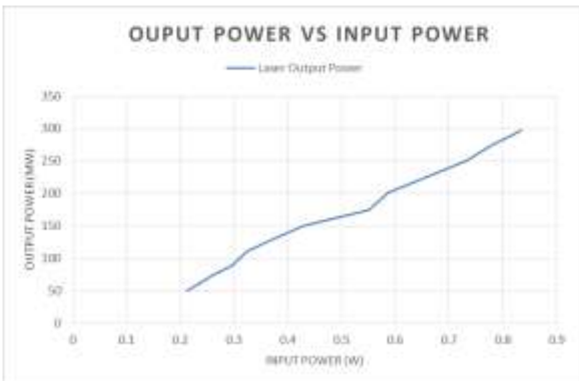

Fig 5: Output Power Vs Input Power

In order to observe a refined laser beam, RG850 filter (diameter: 76.2 mm) was used. This filter prevent the transmission of pump beam through it. So, the beam finally obtained was just the required laser.

When Cr^{4+}: YAG Q-Switch was inserted between the crystal and the output coupler, Q-Switched laser was obtained. The pulse width of the obtained laser was recorded to be around 20-25 ns. Fig. 6 shows one of the pulses that was recorded. The frequency of the laser is in the range of kHz.

The laser was obtained since the resonator cavity was stable i.e. the factors g1 and g2 (discussed earlier) lie in the stability region. The stability graph plotted is shown in Fig. 7. Points corresponding to different value of R_1 werealso plotted to check whether stable cavity was obtained or not.

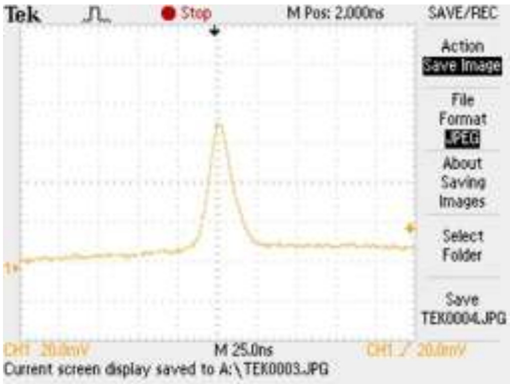

Fig 6: Pulse width of Q-Switch laser

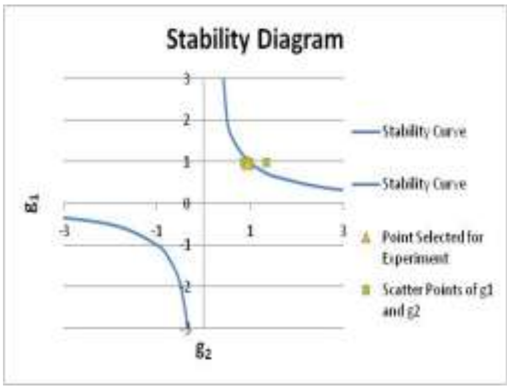

Fig 7: Stability Diagram

IV. CONCLUSION

A stable and efficient end diode pumped continuous wave and Q-Switch Nd: YVO_4 laser has been developed. In spite of all the disturbances from the external environment and internal temperature variations, it was able to generate a consistent output power at a wavelength of 1064 nm with the efficiency of ~36%. Nd: YVO_4 is extremely well suited for passively mode-locked lasers with very high pulse repetition rate and is finding much use in frequency doubled green laser pointers and other small diode laser modules. Neodymium doped laser can be made more effective by using Nd: $LaSc_3$ $(BO_3)_4$ or Nd: LSB. It has absorption bands five times wider, absorption coefficient three times higher and saturation intensity five time bigger than that of Nd: YAG. So, Nd: LSB has a great future prospect.

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