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CHARACTERIZE Q-SWITCHING DYE LASER BY SATURABLE ABSORBER

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Abstract In many applications, the laser beam needs to be focused to a very small spot size, or else the overall brightness of the beam is crucial parameter. In this study, the BeamStar CCD Laser Beam Profiler was used as a diagnostics measurement system of passive Q-switched laser beams. The dye laser was utilized as a source of Q-switching laser. Two materials were used as a saturable absorber inside the laser cavity, which are 1,3'-Diethyl-4, 2'-quinolyloxacarbocyanine Iodide (DQOCI) and Chromium-doped Yttrium Aluminum Garnet (Cr^{4+}: YAG) crystal. The output characteristics of the Q-switch laser posses of a uniphase of TEM_{00} mode. Laser parameters such as beam width, Gaussian Width and correlation were observed at various working distances. In general, the beam spot of passive Q-switch laser are independent with working distances.

Introduction

The short duration pulses of laser are very useful (Kuhn, 1998) as it can melt materials in a very short times interval so that the heat does not dissipate to the area. This is an advanced technology used for cutting small, refined holes on hard materials. This technique is also in the eye surgery (Charschan ed., 1972). Another application is to make use of the time short time-scale pulse to take pictures of fast phenomena (Hoong, 1984), or we can use it for metrology (Hua *et al.*, 1983). One way of achieving high peak power pulses of short duration in a laser system is by Q-switching technique (Sirohi, 1984).

The posibility of using Q-switching lasers was first proposed by Hellwarth (Noriah Bidin, 2002) in 1961. It is a method used for obtaining sharp single, short duration and thus high power lasers. The technique allows the production of light pulses which shortens the output pulse width as compared to those produced by the same laser under a normal operation. In practice, this switching is performed by a variety of methods, such as acousto-optic (Hellwarth, 1961), which is difficult to implement and requires focusing of radiation in an acousto-optic cell in order to reduce the switching time, thus limiting the permissible optical loads. This method and another active type such as electro-optic and rotating prism are complex for installation, alignment and operation and relatively expensive (Koechner, 1976). As an alternative to active methods, lasers can also be passively Q-switched by means of a saturable absorber (Braverman, 1975). The passively Q-switched laser potentially offers the advantages of low cost, reliability, and simplicity in fabrication and operation since it requires no high voltages or fast electro optic drivers. In this technique, a material with high absorption at the laser cavity and prevents laser oscillation until the population inversion reaches a value exceeding the combined optical losses inside the cavity. As the photon density builds up following achievement of a net positive inversion, the saturable absorber rapidly bleaches into a high transmission state thereby Q-switching the laser. Bleaching of the saturable absorber is brought by saturating of the absorption at the lasing medium frequency (Braverman, 1975).

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In this study, a method of Q-switching pulse operation was evaluated using the 1,3'-Diethyl-4, 2'-quinolyloxacarbocyanine Iodide (DQOCI) and Chromium-doped Yttrium Aluminum Garnet (Cr^{4+}: AG) crystal. The purpose of this study is to characterize the output beam of passively Q-switch dye laser.

Experimental Details

There are two types of saturable absorber used in this project. First is an organic dye DQOC which has been dissolved in ethanol. This solution was contained in 1 mm x 1 mm cell. Another one is Cr^{4+}: YAG. The saturable absorber cell was inserted into the laser cavity between the lasing medium and high reflector mirror as shown in Fig. 1.

The dye laser system used in this study is Nitrodye model LN120C. This laser system was operated at the Nitrogen pressure of 25 psi with Coumarin 500 dissolved in ethanol as a lasing medium. The laser system layout is shown in Fig. 1. The plano-convex lens colimates the N_2 beam. A high reflectivity flip-flop mirror turns the beam 90° to pump a dye module. The plano-cylindrical lens focusses the 337.1 nm N_2 beam into dye lasing medium cell. The solution in the saturable absorber cell strongly absorbs light of the dye laser, and this absorption prevents net amplification of light from occuring until a much larger proportion of saturable absorber molecules have been pumped to the upper energy level. If a sufficient number of molecules are excited, the saturable absorber becomes completely transparent to the lasing medium light. At this instant, the laser radiation can reach the high reflector mirror and laser oscillation occurs. Then, there is suddenly a large net amplification and a narrow pulse containing all the stored energy in the lasing medium, develops rapidly. The output coupler allows this pulse to transmit.The output of Q-switched dye laser system was detected by a high speed BPX 65 photodetector. In other to observe the two- and three-dimensional intensity distribution analysis distribution on laser beam, the BeamStar CCD laser Beam Profiler was used as a beam diagnostic system. It comprised a video camera and PC card to image, capture, and store the laser beam profile. The parameter considered in this experiment was working distance between CCD and the dye laser.

RESULTS AND DISCUSSION

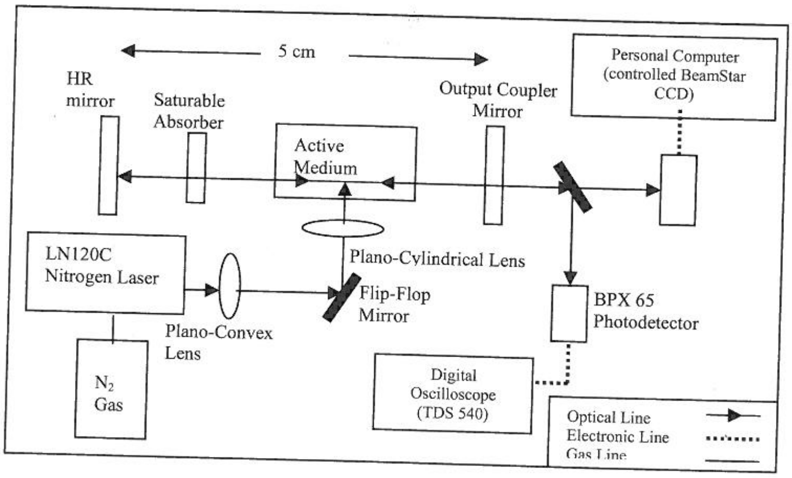

Figure 1. Schematic diagram of passively Q-switched dye

Laser parameters such as beam width, Gaussian Width and correlation were observed at various working distances. The Gaussian fit profile shows how closely the measured beam profile matches a

Gaussian profile. The typical results obtained from this experiment are depicted in Fig. 2. The Gaussian fit profile is displayed on top of both the vertical and horizontal profiles in green.

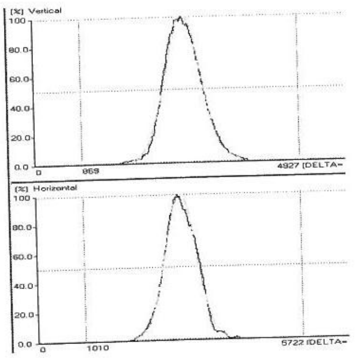

Figure 2. Gaussian profile of passive Q-switched laser beam. (a) Vertical profile; (b) Horizontal profile

Figure 3 shows the typical two- and three-dimensional images of passive Q-switch laser beam. Three dimensional far field transverse beam profile of the Q-switching laser output beam is illustrated in Fig. 3(a). The beams are distributed in the form of Gaussian beam profile. The gain spectrum is relatively quite broad. Two-dimensional image of the Q-switch laser beam is shown in Fig. 3(b). A single spot obtained, indicated that the laser was operated at a uniphase mode. The beam spot is accompanied with beam noise and diffraction effect.

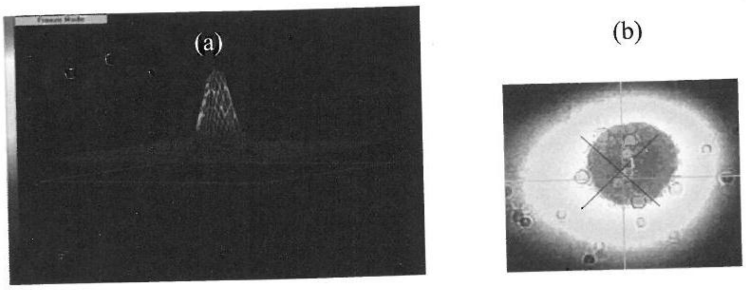

Figure 3. Beam profile of Q-switching laser; (a). Three-dimensional image shows the distribution of Gaussian beam profile (b). Two-dimensional image

The symmetry and uniformity of the laser beam are both indicated that the laser operates in the TEM_{00} mode. This mode is also called the mono-mode. The mode pattern is stable with time and constitutes a spatially coherent output. Thus, TEM_{00} has the lowest beam to be focused to the smallest possible spot.

The percentage deformation calculation from the ideal Gaussian beam then presented as a correlation. The graphs are illustrated in Fig. 4 and Fig. 5 for both DQOCI and Cr^{4+}: YAG saturable absorbers respectively.

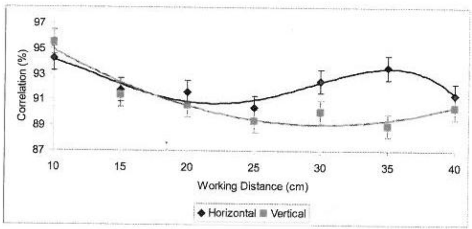

Figure 4. Correlation upon working distances for DQOCI saturable absorber

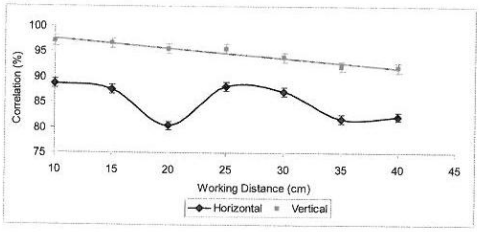

Figure 5. Correlation upon working distances for Cr^{4+}: YAG saturable absorber

As depicted in Fig. 4, the curves show that the correlation percentage for both horizontal and vertical axis of passively Q-switched dye laser beam using DQOCI is nonlinearly decreased with respect to working distance. However, the correlation percentage was found highest at short working distance for both horizontal and vertical axis. At far working distance, the correlation percentage fluctuates.

Figure 5 shows the correlation percentage graph of the passively Q-switched dye laser using Cr^{4+}: YAG crystal upon different working distance. For vertical axis, the percentage inversely proportional with working distance. However, for horizontal axis the percentage seem to be fluctuated. The highest correlation percentages for both horizontal and vertical axis were found at short working distance.

Another parameter, which may be important to be considered is the laser spot size. Some applications require a small spot for high-resolution measurement while others require a larger diameter spot for averaging rough surfaces or for eye safety concerns.

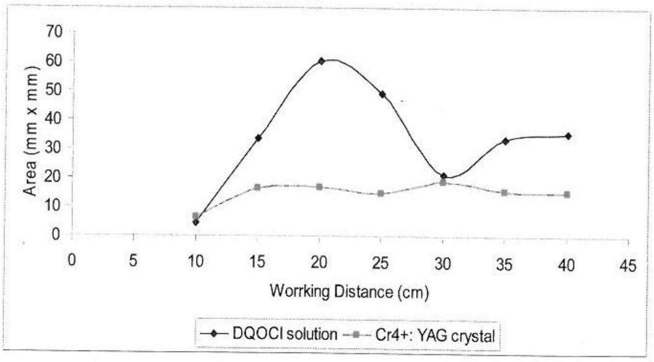

Figure 6. Beam spot area against working distance

Spot area of passively Q-switched dye laser using Cr^{4+}: YAG crystal saturable absorber was found smaller than spot area produced by using DQOCI saturable absorber. As shown in Fig. 5, initially, the spot area of Q-switch laser using DQOCI saturable absorber drastically increased with respect to working distance. Nevertheless, the spot area drops suddenly and become fluctuate, as the distance gets longer. Different with The spot area of Q-switch laser using Cr^{4+}: YAG crystal saturable absorber where initially it gradually increased and remains almost constant at greater working distance.

Conclusion

In this project, the output characteristics of the Q-switch laser posses of a uniphase of TEM_{00} mode. From the analysis, the highest correlation percentage was found at lower working distance for DQOCI and Cr^{4+}: YAG saturable absorber of both horizontal and vertical axis. In general, the beam spot of passive Q-switch laser are independent with working distances.

Acknowledgement

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References

Braverman, L.W. 1975. Controlled Passive Q-Switched For The N_2-Laser-Pumped Dye Laser. Journal of App. Phys. Lett. 27(11):602 – 604.

Charschan, S.S. ed. 1972. Lasers in Industry. Western Electric Series, New York.

Hellwarth, R.W. 1961. Control of Fluorescent Pulsation. Advanced in Quantum Electronics. Columbia University Press, New York. 334 – 341 pp.

Koechner, W. 1976. Solid-State Laser Engineering. Springer-Verlag, New York.

Koh Chu Hua, Joy Trisnawati Halim and Sing Lee. 1997. Nanosecond Photography of sparks (simulation of lightning dynamics). A Technology and Engineering Programme (TERP) for Junior College Students.

Kuhn, K. J. 1998. Laser Engineering, Prentice Hall, USA.

Ng Kwan Hoong. 1984. Laser in Ophthalmology. Laser and Plasma Technology. Proceedings of the First Tropical College on Applied Physics. December 26, 1983 - January 14, 1984. Universiti Malaya, Kuala Lumpur. 656-665 pp.

Noriah Bidin. 2002. Teknologi Laser. Penerbit UTM, Skudai, Johor.

Sirohi, R.S. 1984. Laser technology in Metrology. Laser in Ophthalmology. Laser and Plasma Technology. Proceedings of the First Tropical College on Applied Physics. December 26, 1983 - January 14, 1984. Universiti Malaya, Kuala Lumpur. 481-501.