CHAPTER 1

INTRODUCTION

1.1 Literature Review

Human beings are really clever in making use of different kinds and forms of energy. Laser material processing relies on laser systems of desired properties. An inspiring thing in laser processing is the application of ultra-short pulsed lasers. Ultrafast lasers can give scientist opportunities to probe the behavior of matter when exposed to intense radiation and do studies in fields such as astrophysics, general relativity and quantum mechanics.

This ultrafast laser currently enable scientist to observe the occurrence of the fastest chemical reaction (Kodymova *et al*., 2004). This is an advanced technology used for ionizing all material within a small area without any heat or mass flow affecting the surrounding area (Charschan, 1972) and carry out precise micromachining (Liu *et al*., 1997). This technology is also used to design high density, high-speed communications networks, which an ultrafast laser's bandwidth is equivalent to millions of telephone calls. Another application is to design compact particle accelerators and generate fusion energy (Lerner, 1998).

The ultrafast lasers can also imitate the conditions at the center of stars allowing astrophysicists to experiment with possible ways in which stars form and explode in supernovas. These high powered lasers can focus the power of all sunlight falling on Earth onto a spot a tenth of a millimeter on a side, accelerate electrons close to speed of light and generate pressures hundreds of time those of light and create magnetic fields a billion times of Earth (Lerner, 1998). One way of achieving these high power pulses with short duration is by Q-switching technique.

1.2 Q-switching Laser

The power output may be increased by Q-switching, which is achieved by exciting the laser medium so that a population inversion occurs but delaying the application of feedback from the axial mirrors (Hellwarth, 1961). On the simplest way, we can define the Q-switching as a method of using an optical switch inside the laser cavity. This optical switch has two states; it's open when the radiation pass through the switch undisturbed and closed when the radiation cannot pass through the switch. Switching the laser system means transferring the system from on to off or the other way.

The possibility of Q-switching laser was first proposed by Hellwarth in 1961. In practice, Q-switching can be achieved by deflecting the beam at the high reflecting mirror mechanically (Collins and Kisliuk, 1962) or by acousto-optic (Koechner, 1976) or electro-optic (Hellwarth and McClung, 1962) devices or by using an opaque saturable absorber (Soffer, 1964) that bleaches transparent when the fluorescent light output reaches a given level. McClung and Hellwarth made the first experimental observation of Q-switched pulse behavior in 1962 using an electro-optical Q-switch in a ruby laser.

Electro-optic Q-switches employs materials that exhibit birefringence under an applied electric field (Kelin, 1998). The advantages of this pure electronic control of Q-switching are many. Such as, the fast switching times, the precise control over, and flexibility of Q-switching and ease to synchronization of the modulation with electronics and measuring apparatus. However, the existence of a Kerr cell (or other electronically controlled switching) inside the laser cavity has presented many problems. They are usually fabricated from crystal such as KDP or $LiNbO_3$, which are hygroscopic and prone to damage, by the laser beam. The polarization requirements mean that the laser beam must be polarized. These Q-switches also require some cleverness in the design of the electrical signal without transients. This combination of factors means that the electro-optic Q-switches are typically used in high peak power pulsed lasers, as well as in high gains CW lasers.

Acousto-optic Q-switches, which employ materials such as quartz that exhibit a change in the index of refraction when the material is acoustically excited have the advantages of being low-loss elements when not Q-switching. In contrast with the electro-optic crystals, acousto-optic crystals have high damage thresholds and are typically not hygroscopic. However, the Q-switches generally require high-power RF power supplies at 20 to 60 W, 50 to 150 MHz. This combination of factors means that acousto-optic Q-switches are typically used in low-gain cw lasers. Their most common application is in continuous wave Nd: YAG Q-switched and mode-locked laser systems (Koechner, 1976).

Another method to Q-switch a laser cavity is incorporating a mechanical device within the cavity that blocks the laser beam. The first mechanical Q-switch used a rotating chopper (Collins and Kisliuk, 1962). However, the choppers are slow and vibration-prone, and such techniques were soon abandoned in favor of rotating mirrors and prisms (Benson and Mirachi, 1964). With rotating mirrors, the approach is to spin the mirror using high-speed motor. Such designs usually incorporate a multisided mirror or multiplicative optical geometries so that several reflections are possible for each rotation (Daly and Sims, 1964). However, rotating mirror Q-switches are prone to alignment difficulties because each face of the mirror must be aligned to within a fraction of miliradian. Although the mechanical Q-switches are the simplest and less expensive, the high rotational speed means that the devices are noisy and process relatively short lifetimes. Furthermore, mechanical components are not robust in harsh environment.

The first three methods of Q-switching are active types, where the switching of the laser light occurs externally. Besides the active type, which is difficult to implement, complex for installation, alignment and operation, laser also can be switching passively. Passive Q-switching received its name from the action of generated radiation itself (Smith and Sorokin, 1966). This technique potentially offers an advantage of low cost, reliability and emission of pulses with a relatively narrow linewidth (Koechner, 1976). It is also simple in fabrication and operation since it requires no high voltages or fast electro-optic devices. Passive Q-switches can be used with pulse pumped systems only because a CW pumped laser never produces sufficient fluorescence to bleach the dye (Kuhn, 1998).

As summary, the reading of all the papers and articles on Q-switching applications and techniques has driven us even stronger to study, diagnose and characterize the fundamental of Q-switching laser. Although it can be achieved by various techniques, this study on passive Q-switching laser and the focus of this research work will be on the materials used as saturable absorber and how to improve the laser outputs.

1.3 Passive Q-switching

Passive Q-switching laser exploits the bleaching of saturable materials. The rising flux within the laser is capable of decreasing the absorptivity of certain saturable absorber placed in the laser cavity. The sudden decrease of absorption has the same effect as the removal of an obstacle in the path of the beam. When properly adjusted, these lasers containing saturable materials trigger themselves to emit a giant pulse.

In the earliest experiments with saturable absorber, Master and Murray (1965) who used an absorbing dye smeared on a microscope slide, and Grant (1963), who used an aluminized Mylar film, produced light pulses of quality and efficiency comparable to that achieved with Kerr cell switches (Geller *et al.*, 1963). However, the absorber was always damaged. The optical saturation in these instances was presumably caused by the evaporation of the thin absorber so as to render the absorber transparent. Subsequently, saturable absorbers have been found which show little or no damage after producing a good quality giant pulse (Soffer, 1964; Sorokin *et al.*; 1964, Kafalas *et al.*, 1964; Bret and Gires, 1964). These employ the saturation of some transition which, because it has a high absorption cross section per absorbing molecule at the laser frequency, requires relatively for photons absorbed, rendering their normal value.

Sorokin *et al*. (1964) found that metalphthalocyanine dyes, dissolved in either nitrobenze or chlornaphthalene (the latter showed some deterioration after several pulses) produced good giant pulses when placed inside the laser cavity. Apparently, the threshold pump energy was not appreciably changed (the actual value was not given). Soffer (1964) has achieved giant pulses of exceptional spectral purity and normal energy content using a saturable absorber of dilute Cryptocyannine. To produce these high quality pulses, 3000 J pump energy was required, as compared to 900 J for normal operation. Kafalas *et al*. (1964) have also used an absorber of Cryptocyannine (dissolved in methanol) to achieve giant pulse outputs. No deterioration of the Cryptocyannine was observed.

All of works explained above are passively Q-switched solid-state laser. Braveman (1975) have demonstrated the first and only passive Q-switching for Nitrogen-laser-pumped-dye-laser. He used a DODCI as a saturable absorber inside the dye laser cavity (the actual solvent type and concentration value was not given). This experiment produces single high-repetition-rate high peak power tunable subnanosecond pulses. However, this experimental set-up makes used a wide space in the laser cavity. The Avco model C950 nitrogen laser source used in this study showed a thermal distortion dominated the mode structure after 50 pulses per second (pps).

1.4 Research Objective

The main objective of this research is to study the saturable absorber material for passively Q-switched nitrogen-laser-pumped-dye-laser. This includes diagnosing the dye laser in order to utilize the system at its optimum performance. Then, characterize the output of Q-switching laser by altering some laser parameters.

1.5 Research Scope

Several materials are determined as saturable absorbers. The dye laser pumped by nitrogen laser is utilizing as a source to be switched. The dye laser cavity is aligning to get its best performance. An external trigger unit builds for the dye laser in order to get a single shot. The photodetector also builds to detect the laser beam.

1.6 Thesis Outline

This thesis is divided into 7 chapters. The first chapter is the review of some applications of Q-switching laser. Previous research related to miscellaneous Q-switching methods and passive Q-switching also presented. This chapter also emphasizes the aim of the research.

Chapter II reviews the background or the theory related to the research. This will cover the basic theory of Q-switching such as quality factor, Q and pumping mechanism. This chapter also explains the various methods of Q-switching and briefly describes the mechanism of passive Q-switching.

Chapter III describes the sample preparation and methodology for passively Q-switched dye laser. This would include image processing software and experimental setup.

Chapter IV discusses the diagnosed results of dye laser. Various laser parameters are tested such as wavelength, cavity length, working distance and repetition rate in order to determine the current performances of dye laser as a source to be switched.

In chapter V, the pulse width and output energy of passively Q-switched dye laser in various manners are presented. These experimental results were compared with the current standard dye laser performances.

Chapter VI presents the diagnostic analysis of passive Q-switches beam. BeamStar CCD Laser Beam Profiler was utilized as diagnostic system.

Finally, the conclusions of the project are made in chapter VII. includes the summarization of the whole project, the problems involved and experience during performances of the project and some works to be carried out in the near future are suggested.