Chapter 1 Introduction

1.1 Brief Review

The solid state laser uses a solid crystalline material as the lasing medium and is usually optically pumped. Solid state lasers should not be confused with semiconductor or diode lasers which are also 'solid state' but are almost always electrically pumped.

Solid state lasers are used in all sorts of applications including materials processing (cutting, drilling, welding, marking, heat treating, etc.), semiconductor fabrication (wafer cutting, IC trimming), the graphic arts (high-end printing and copying), medical and surgical, rangefinders and other types of measurement, scientific research, entertainment, and many others where high peak power and/or high continuous power are required. A high energy pulsed YAG laser has even been used in rocket propulsion experiments (well, at least to send an ounce or so aluminum projectile a few feet into the air using just the pressure of photons!). The largest lasers which have the highest peak power in the World are solid state lasers. Many of the laser projectors for light shows and for other laser displays use solid state rather than gas lasers like argon or krypton ion laser. And, that green laser pointer is a laser.

1.2 Motivation

In the laser theory, there are parameters to describe the laser resonator called the g-parameter. The g_1 or g_2 parameter is defined as $g_{1,2} = 1 - \frac{L}{R_{1,2}}$, where L is the cavity length and R is curvature of the output coupler. When g_1g_2 is between zero and one, the laser system is geometrically stable (ref. [1]). The laser would be considered as a stable laser system. It is if we use a CW pumped, the output would be also CW; if it is pulse-pumped, the output would be pulse, too.

However, when g_1g_2 is equal to some specific values between zero and one, the laser output would become unstable. This means that even with a CW pumping light a dynamic output may result in the form of pulsation, chaos, quasi-periodic etc... It has been found experimentally that instabilities occur in almost any laser systems if the output power is increased above some critical value. Above this value, it is not possible to obtain a total output power that is constant in time. In many cases, the spatial distribution is not stable, either. It had been suggested that the instability as mentioned above is due to the transverse mode interaction (ref. [2]) and introduce a second threshold to the instability.

On the base of beam propagation in a laser cavity that contains a homogeneously broadened gain medium, Melnikov (ref. [3]) constructed and analyzed a three dimensional point map that presented the evolution of the beam parameters (spot size and wave-front curvature) together with the field intensity with which to model the nonlinear laser dynamics. They found that in a uniformly pumped laser with a high-loss cavity the laser has a continuously smooth quasi-periodic threshold throughout the geometrically stable region, except that some singular points that correspond to transverse mode degeneration (ref. [4]) may become chaotic at high-power pumping.

However, by using a diffraction integral and rate equations, Hollinger and co-workers (ref. [5-7]) studied the instability of single-longitudinal but multitransverse modes. They found that, in a laser with a high-loss cavity and uniform high-power pumping, the laser's output appears to be chaotic at the configurations that have g1g2 = 0.4 but to be only quasi-periodic at g1g2 = 0.5, which corresponds to the 1/4-degenerate configuration.

Obviously, there is a contradiction that whether chaotic behavior exits or not. If it does exit, what would the cavity configuration be? And another feature we wish to find out is how does the instability threshold depend upon the cavity configuration? Is it smooth or thing some else? Thus, we would like to make these questions clear and to study the dynamical behavior of this system both theoretically and experimentally.

1.3 Aim of this work

As we mentioned in the previous section, we will pay our attention on the instability of the laser system induced by the mode interaction. For simplicity, we choice Nd:YVO_4 laser system which is a simple two-mirror system. We wish to figure out that:

1. The instability threshold is smooth or thing some else.
2. The cavity dependence of the instability threshold.
3. The dynamical behavior of the laser output around degenerate configurations.
4. The mechanisms that induce the instability.

1.4 Organization

We will introduce some theory of our laser system and the simulation model, including Huygens' integral, thermal effect and rate equation in chapter two. Then introduce our laser system setup and some special skills of the experiment in chapter three. In chapter four, we will discuss our experiment and simulation results. Final, we conclude these results in chapter five.