CHAPTER 1

INTRODUCTION

Tunable diode lasers are compact, versatile sources and have a wide range of applications for coherent optical communication [1, 2], optical spectroscopy [3, 4], and precision metrology [5]. Frequency control is also necessary for the growing need for such lasers with high spectral purity [6]. External-cavity operation of semiconductor laser is attractive for applications requiring greater spectral purity and frequency stability than can be obtained from a solitary laser diode (LD). For example, the main difficulty in using diode lasers in most atomic physics experiments is the problem of tuning them to the desired wavelength, usually that of some atomic transitions. And for most coherent applications, the linewidth and frequency stability of regular single frequency lasers are not sufficient for acceptable system performance. The external-cavity technique has been shown to yield substantial improvements in the spectral quality of diode lasers, with linewidth reductions from tens of MHz to hundreds of kHz routinely attainable. A properly designed external-cavity diode laser (ECDL) operates on a single external-cavity longitudinal mode. Truly phase-continuous tuning without mode hops is also possible. The use of an external filter allows tenability across the wide gain bandwidth of the semiconductor gain media. The very narrow linewidth, excellent phase stability, and a wide tuning range make them ideal sources for coherent communication systems. Areas of precision optical physics such as atomic clocks [7], frequency and length standards [8] also can be realized by tunable ECDL systems.

1.1 Motivations

As introduced above, external-cavity diode lasers play an important role in many applications. They are typically tuned either mechanically or electronically. Almost in all of the ECDL systems, the cavity fine-tuning is achieved by movement of the feedback device driven by a piezoelectric transducer (PZT), which has hysterisis and aging problems. Stable mounting of the PZT to the feedback elements, grating or mirror, is required. Wavelength fine-tuning by inserting a single glass plate in an ECDL has been recently reported [9]. By tilting the 2 mm-thick intracavity glass plate in a tunable 633-nm ECDL that changes the optical path, a continuous tuning range of 1.8 GHz was obtained. The introduction of the intracavity glass plate makes fine-tuning of the cavity length more convenient than traditional ones. The coarse-tuning and fine-tuning devices are completely separated. However, this approach still requires mechanical movement of a relatively bulky component. It is desirable to be able to tune the laser frequency electronically. Electronically tuning allows fast and accurate wavelength tuning by varying the applied driving voltage only. While the voltages required for conventional electrooptical devices, e. g. bulk $LiNbO_3$ crystals are high. And it is not convenient when use acousto-optic tunable filters because of the deflected output beam. One such approach, utilizes the electro-optic properties of liquid crystals. Several types of liquid crystal elements have been successfully developed as intracavity tuning elements in ECDL systems. Liquid crystal tuning elements require low-voltage operation and low power consumption. They are good candidates and have potential to be used in ECDL systems for cavity fine-tuning with simple constructions. But the laser characteristics such as frequency and power fluctuations, laser linewidth, etc. when employing intracavity LC elements, and the performances of its applications especially compared with the typical mechanical tuning ECDL's are required to be further investigated.

1.2 Scope and description of the study

This section is to outline the scope of a PhD research program by the author of this thesis, and describe the structure of the thesis which contains most of the achievements of the study. The scope of this study can be laid down in two facets as follows:

(i) To develop an ECDL with an intracavity liquid crystal element, and investigate the features, such as power fluctuations, response time and switching characteristics, of such a laser system. Study on the mode-hop-free fine-tuning mechanism of the developed ECDL.

(ii) To use the developed ECDL for some applications, such as sub-Doppler spectroscopy investigation and wavelength stabilizations. To compare the performances with the commercial product. Study on the potential and feasibility of the developed ECDL applied to liquid crystal cell gap measurements, which is an important parameter in liquid crystal display industry.

This thesis consists of seven chapters including this introduction, background information and literature reviews (Chapter 2-3), and studies into two facets of the ECDL with an intracavity liquid crystal element (Chapter 4-6), as well as conclusions and recommendations (Chapter 7).

Chapter 2 introduces tunable ECDL systems. Review of tuning mechanisms including typical mechanical tuning, and electronically tuning by electro-optical and acousto-optical methods.

Chapter 3 is dedicated to review use of liquid crystal elements for tuning of the ECDL.

Chapter 4 describes the development of an ECDL with an intracavity liquid crystal cell. The fundamental principle of the liquid crystal elements used in the study and the operation principle of mode-hop-free tuning are described.

Chapter 5 demonstrates the fine-tuning results of the ECDL developed in the study. Characteristics of the ECDL are investigated.

Chapter 6 presents the applications of the developed ECDL in spectroscopy, wavelength stabilizations, and liquid crystal cell gap measurements. The performances compared with a commercial product are demonstrated.

A discussion and conclusion to the work is given in Chapter 7. Recommendations of further work are also given in this chapter.