CHAPTER 1: INTRODUCTION

1.1 Three Dimensional Topography

Advancement in the areas of laser, robotics, and optical image processing has led to the development of three dimensional (3D) topographic systems that are used in a wide variety of applications. The 3D topographic system works by optically generating and projecting a sequence of laser beam patterns on a target surface [2]. The pattern sequence, which is space-coded, is recorded using a viewing camera at an appropriate perspective. The recorded information is then used to obtain 3D spatial coordinates of all the points on the surface of the object using rigorous mathematical techniques.

The wide spread use of the 3D topography has been due to various factors including:

- High degree of precision which is consistent and repeatable. This is unlike the case of a human whose performance might degrade due to fatigue or boredom.
- The system can be placed at locations that are not accessible or suitable to humans.
- *A priori* knowledge of reliability of the process.
- Possibility to gather information at any desired rate by programming the system accordingly, while online control enables to collect data at any instant.
- Implementation of quality checks for the entire product line instead of using a limited number of samples (as is the case with human implementation).
- The above advantages result in better quality, less wastage of time and materials, improved profits, and better working environment for the laborers.

Examples of the application of 3-D topography for industrial purposes include its use as a computer controlled sensor-manipulator also known as an intelligent robot in the assembly line of industries [7]; as an automated visual inspection system in quality control of products [9]; and as a biometric mapping system in telemedicine [6].

1.2 Biometrics

Biometrics is a rapidly evolving technology that is widely used in a number of medical, private, and public sector applications. In technical terms, biometrics is an automated technique to measure physical characteristics or personal traits of any living being. Some of the physical characteristics are the features of the eye, fingerprints, skin pores, wrist veins, facial features, chemical composition of body odor, and skin pores [30]. The handwritten signature samples, keystrokes in typing, and an individual's voice samples are some of the personal traits used in biometrics. Biometrics is used in medicine for fitting of medical prosthetics and orthopedics; planning and documentation of reconstructive surgery; and in patient positioning during treatment [6]. A number of Government agencies like U.S. Immigration and Naturalization Service, Federal Bureau of Investigation, and Department of Motor Vehicles, to name a few, use automated biometrics-based identification and verification systems. Some of the commercial applications of biometrics include design of animation pictures and design of garments for people of different sizes in textile industry. The primary reason for biometrics gaining popularity is that it uses data that are directly attributed to the human or living being of interest. For instance, this is of utmost importance in reconstructive surgery, where each measurement is unique to a particular individual. Similarly, for identification purposes biometrics is a better option compared to use of equipment like badges and keys that can be stolen, lost, or misplaced, since biometric scanning is not susceptible to any such problems.

1.3 3-D Topography in Biometrics

Use of 3D topography for biometric application is a topic of research in many areas of medicine, particularly in radiation therapy and neurosurgery [6]. Patient positioning is an important aspect in the above mentioned areas. For example, in the treatment of a cancer, the patient is treated with radiation several times a day at the same part of the patient's body in order to kill the tumor. For the treatment to be effective, the patient should be placed at the same position relative to the instrument that emits the radiation. This is usually achieved by using tattoo marks as the reference and having various positioning devices whose settings are customized for each patient. The 3D system in conjunction with the radiation treatment equipment can be used for real time positioning of the patient. Once the desired position is known, using online data acquisition and feedback mechanism, radiation equipment is suitably placed without any external reference marks. Since this is done in real time and since the process is automated, both the margin of error in positioning and time required for positioning are considerably reduced. Another example of the application of a 3D topographical system, is in neurosurgery where it is necessary to align the patient with robotic surgical systems [6]. The two critical features of the 3D systems used in biometry are its accuracy and its speed of operation. The allowable tolerance for the measurements made by the system is in 0.1 to 1 millimeter range. The measurements, even though made over a large area need to be completed as quickly as possible to guarantee zero discomfort to the subject involved.

DCS Corporation developed a 3D topographic system known as the 3D Area Mapper for biometry. The areal mapper satisfied the accuracy and the speed requirements to be used in medical applications. However, the main constraints faced by DCS were the large size and the limited power output of the illumination module used in the system. The laser source and the driver electronics discussed in this thesis are part of the solution that was suggested to DCS Corporation in order to upgrade their existing system.

1.4 Thesis Objective and Overview

The primary objectives of this thesis are:

1. To design, develop, implement, and test a miniaturized cost-effective laser diode/fiber illumination system.
2. To propose and design the driver electronics for the Spatial Light Modulator (SLM) to be used in the miniaturized Light Illumination Module (LIM).

The research is part of a project jointly funded by Virginia Center for Innovative technology and DCS Corporation in Alexandria, Virginia. The goal of this research program was to develop a miniaturized LIM to be used along with a computer, a laser diode/fiber system, and a Charge-Coupled Device (CCD) camera that constitute the Next generation 3-D Areal Mapper. This system, based on the DCS 3-D Areal Mapper, was designed and fabricated in the Fiber and Electro-Optics Research Center (FEORC) and is used to deliver three-dimensional surface information of mapped objects. DCS Corporation will use this next generation 3D areal mapper in turbine blade rework applications and patient positioning applications. The most important issue in the design and implementation of the system was to keep its overall size to a minimum. The system that was delivered to DCS Corporation had a volume of 114 cubic inches and the output from the system was a 256 x 256 beamlet pattern with an integrated output power of 1mW. The system used an improved design for the holographic element and its mechanical orientation. The reduction in size was made feasible by replacing the commercially available driver for the SLM with a new compact electronic design and necessary interface software. The supporting laser source that was supplied to DCS along with the 3-D system incorporated a high power laser diode and advanced optical coupling between the source and a Polarization-Maintaining (PM) single mode optical fiber. The laser system with a volume of 73 cubic inches and power of 15mW at the output of a pigtailed optical fiber was fabricated at a cost of $2,000.

Chapter 2 describes the theory and construction of a surface profiling system; the principle of operation of the Light Illumination Module (LIM) developed by FEORC; its advantages and application; and the contribution of the thesis to the LIM. Operation of a laser system and description of a diode laser system follows in Chapter 3. Chapter 4 gives a detailed description of design, fabrication, and testing of the diode laser/fiber system. Chapter 5 explains the microprocessor based design of SLM's driver, the hardware interface, and the software interface used between the host computer and the SLM. Chapter 6 provides the conclusions derived from the thesis and the future scope for the modules.