Low Cost, Short Wavelength Fiber Bragg Grating
Strain Sensor Systems

CHAPTER 1
INTRODUCTION

Since fiber Bragg gratings (FBGs) were first produced in 1978 by Hill *et al*. in an experiment to examine nonlinear optical effects in germanium doped optical fibers [1], they have found widespread use in telecommunications and sensor systems as a replacement for bulk optical components such as mirrors and filters. Plainly defined, fiber Bragg gratings are long, periodic changes in the refractive index along a length of fiber core, which cause the reflection of a narrow band of wavelengths. Exposing a photosensitive fiber core to an interference pattern of intense UV light generates this change in index. Despite their simple design, FBGs can be used as elements of active devices such as fiber lasers and frequency stabilized diode lasers, as well as passive devices such as filters, feedback mirrors , and dispersion compensators [2]. In many of these devices, bulk optics can be used, but considerable design efforts must be taken to limit coupling losses into and out of the fiber waveguide. However, by using FBGs, such devices can be placed in-fiber with very low transmission and reflection losses and increased stability. Although telecommunications is a major application of FBG devices, more recently they have also been used in sensitive sensor applications.

Fiber Bragg gratings are aptly suited for sensor systems mainly due to the characteristics of the optical fiber in which they are formed. Optical fiber is unaffected by outside electromagnetic interference, electrically isolated, light weight, small, and capable of spanning great lengths, making FBGs ideal for use in hostile conditions where electrical sensors are impractical. Fiber Bragg gratings have already been developed to sense stress/strain, temperature, pressure, and chemicals with extreme accuracy [3]. For example, at 1550 nm, a fiber Bragg grating has an axial strain sensitivity of 1.2 pm/μ∈ and a temperature sensitivity of 13.7 pm/^{o}C [4]. FBGs can also be designed to measure strain and temperature simultaneously [4,5].

Although FBG sensor systems are very useful and effective, they are also fairly expensive. Because the telecommunications industry uses sources and detectors in the 1300-1550 nm wavelength range, where silica fibers have minimal loss and material dispersion [6], the majority of commercially available FBGs are within this wavelength range. Although using these particular wavelengths is unnecessary for sensor research since FBGs can be made at any wavelength simply by changing the interference fringe spacings of the incident UV light, most sensor researchers do not manufacture their own gratings or special order gratings at other wavelengths. On the other hand, light sources and detectors for the telecommunication wavelength range are considerably more expensive than shorter wavelength devices in the 750-900 nm range. A fiber Bragg grating strain sensor system utilizing lower cost, shorter wavelength light sources and detectors and standard telecom fiber would be more cost effective than a 1300 nm strain system if the costs of fiber Bragg gratings for any wavelength were equivalent. A new writing method recently devised by Stump *et al.* and described in section 2.4 makes it possible to fabricate FBGs over a wide wavelength range using a single phase mask [7]. This greatly reduces cost of producing gratings at multiple wavelengths. Because of the availability of this fabrication technique, it is possible to develop a fiber Bragg grating strain sensor system using low-cost CD-ROM laser sources around 780-850 nm and Si PIN photodiode detectors.

The focus of this thesis is the development of a less expensive, short wavelength, FBG strain sensor system. One of the simplest FBG strain sensors is a reflection system as depicted in Figure 1.1. A broadband light source, such as an LED illuminates a single FBG. A change in strain along the FBG sensor will result in a center wavelength shift in the reflected spectrum. This shift can then be detected. To produce such a system requires the development of broad bandwidth pigtailed sources, short wavelength FBGs, a recoating process to protect the gratings once they are made, and techniques to splice together all the various fiber components. This thesis details this process.

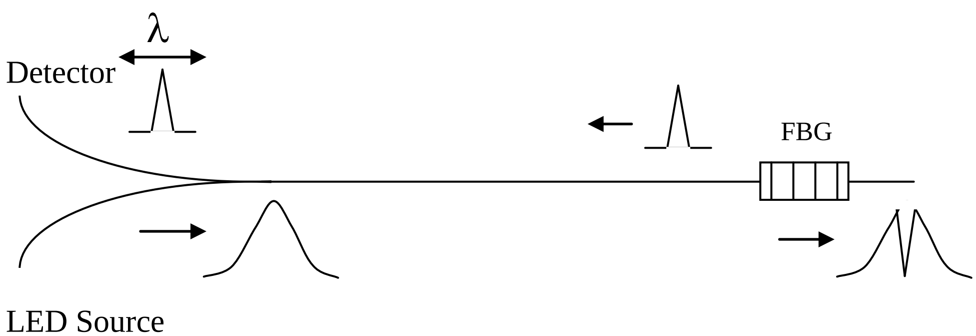

Figure 1.1: Basic reflection FBG strain sensor

Chapter 2 presents a review of fiber Bragg gratings including their 30 year history, different types of gratings, fabrication methods, and their applications, including sensors. A detailed description of the short wavelength sensor system development and assembly is given in Chapter 3. Chapter 4 contains results and a comparison of the short wavelength strain system and a 1300 nm strain system assembled in a similar manner. Finally, in Chapter 5, I present my conclusions and a short discussion of future research ideas.