System Construction for the Measurement of Bragg Grating characteristics in Optical Fibers

Douglas P. West* and Dr. Robert S. Rogowski

Non-Destructive Evaluation Sciences Branch
Fiber Optic Sensors Group
MS 231
NASA Langley Research Center
Hampton, VA 23681

*Langley Aerospace Research Summer Scholar

ABSTRACT

Bragg gratings are used to measure strain in optical fibers. To measure strain they are sometimes used as a smart structure. They must be characterized after they are written to determine their spectral response. This paper deals with the test setup to characterize Bragg grating spectral responses.

INTRODUCTION

Bragg gratings are a photo-induced phenomena in optical fibers. The gratings can be used to measure strain by measuring the shift in wavelength. These gratings have real world applications as shown by R. M. Measures et al., 1993. They placed the fibers into a smart structure to measure the stress and strain produced on support columns placed in bridges. As the cable is subjected to strain the grating causes a shift to a longer wavelength if the fiber is stretched and a shift to a shorter wavelength shift if the fiber is compacted. Our applications involve using the fibers to measure stress and strain on airborne systems.

There are many ways to write Bragg gratings into optical fibers. Our focus is on side writing the grating. Our capabilities are limited in the production rate of the gratings. C. G. Askins et al., 1994, was able to side write fibers using an on-line fiber draw, but we have to write the fiber one grating at a time since we do not have drawing capabilities. We are writing Bragg gratings into AT&T's "Accutether" 9% germania-doped optical fiber using the "Phase Mask" Method as described in Morey et al., 1994. When the Bragg grating is written into a fiber it becomes a permanent fixture. We are writing the grating to be centered at 1300 nm because that is the standard phase mask wavelength. The optimum wavelength for writing the fiber is at 240 nm. Since our laser has a wavelength of 266 nm, which is the fourth harmonic of a ND:Yag, we are loading the fiber with hydrogen to produce the effect necessary to write the grating

EXPERIMENTAL

The grating is written by passing an UV beam through a phase mask, which produces an interferometric pattern. Care must be taken to ensure complete stability of the fiber during the writing process. The writing of the grating is energy dependent. The laser we are writing with has an output of 10 mJ/pulse @ 10 Hz. (This correlates to 100 mW.) After the grating is written it must be characterized before use in a smart structure.

I developed software to interface with a Hewlett Packard 70951A Optical Spectrum Analyzer. I wrote programs in the "C" computer language to control the sampling rate and store the data in a user named file for further data presentation. I connected all the equipment together and built a cable for serial port communication from the Apple computers. Qudus Olaniran was my technical advisor for problems I had with program development and Mark Froggatt was my direct research supervisor.

The programs written transferred data back and forth over a serial port, through a National Instruments RS-232 - GPIB converter and to the spectrum analyzer. The serial port communication code was already written by Qudus for another purpose and needed minor changes. The main development of the software was in the controlling of the spectrum analyzer and the storage of the received data.

The first code written was a complete measurement response data collection package. This code was written in "C" language using a development package named "Think C v5.0" by Symantec. These programs were developed using a PowerBook 520c as the controlling device to give the spectrum analyzer complete portability. After that was accomplished I offered the ability of controlling the sampling rate, thereby speeding up the data collection process.

The next batch of programs controlled the output of a National Instruments Digital to Analog converter card to drive a laser thermally. This application also measured the response of a fiber and stored the data in a user named file. This code was also written in "C" language, but the development package was changed to "Code Warrior" and the computer was changed to a PowerMac 8100 AV model.

EQUIPMENT SETUP

National Instruments GPIB - 232CV

The National Instruments GPIB - 232CV is a device that allows connection of a device with a RS-232 port to a GPIB bus. It allows "transparent" conversion of data between the two ports - meaning that control codes aren't necessary to inform the converter to do what it was designed to do. The set up codes for the National Instruments converter are set internally using dip switches. The switches are set up for the following data transfer.

Internal settings of the dip switches

1 = on   0 = off
U22 10110111 - C mode, CR termination, address 23
U20 01001101 - Xon/Xoff protocol disabled, 8 bits/character, 1 stop bit,
parity checking disabled, 9600 baud

In C mode operation the GPIB - 232CV operates as a controller. It asserts an *IFC (interface clear) for 500μsec when the device is powered up. This initializes the bus and makes the converter the controller. It is important that all equipment connected to the bus is on and initialized before the converter is powered up, otherwise it will interfere with the initialization procedures.

The information sent to the GPIB - 232CV from the serial port is buffered until the device on the GPIB is ready to receive data. After the device on the GPIB has completed the instructions it sends a data ready signal back to the converter. The converter receives the data and transmits the data back to the computer, the information isn't buffered before being sent to the device on the serial port.

Our converter is set up to terminate in carriage return . This allows us to send the character "\n", in "C", to tell the converter it needs to change from listen mode to talk mode so information can be transferred from the device on the GPIB to the serial port. The converter will stay in the talk mode until a character is received on the serial port from the computer. At this time the converter changes to listen so instructions can be sent to the receiving device.

The address is set to 23 because that is the address of the Hewlett Packard Optical Spectrum Analyzer.

The converter transmits data in 8 bit words with 1 stop bit, at 9600 baud.

National Instruments NB-MIO-16XH Interface Board
pn 180675-11 Rev. C

The National Instruments NB-MIO-16X Interface Board is a multifunction control board. It can be used to control analog, digital, and timing input/output operations. Analog to digital conversions, control of test equipment, and analysis of incoming signals are also possible. We used it to drive the laser temperature set-point control to +/- 500mV, and to +/- 750mV and to control the timing of the data accumulation.

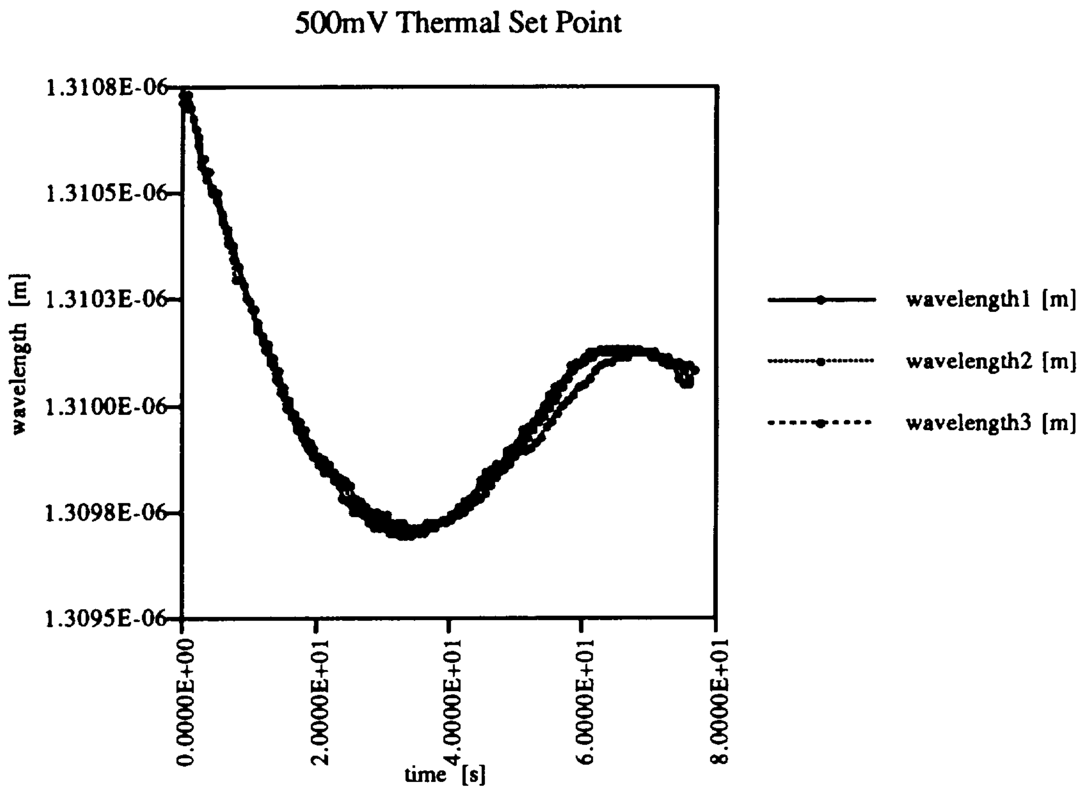
ACKNOWLEDGEMENTS

I would like to thank the following people for their contributions. Mark Froggatt for the mentorship and the precise outlay of project goals and direction, Qudus Olinaran for his expertise in programming, Nurul Abedin for the optical theory discussions and technical writing assistance, John Deaton for the diagrams on writing Bragg gratings.

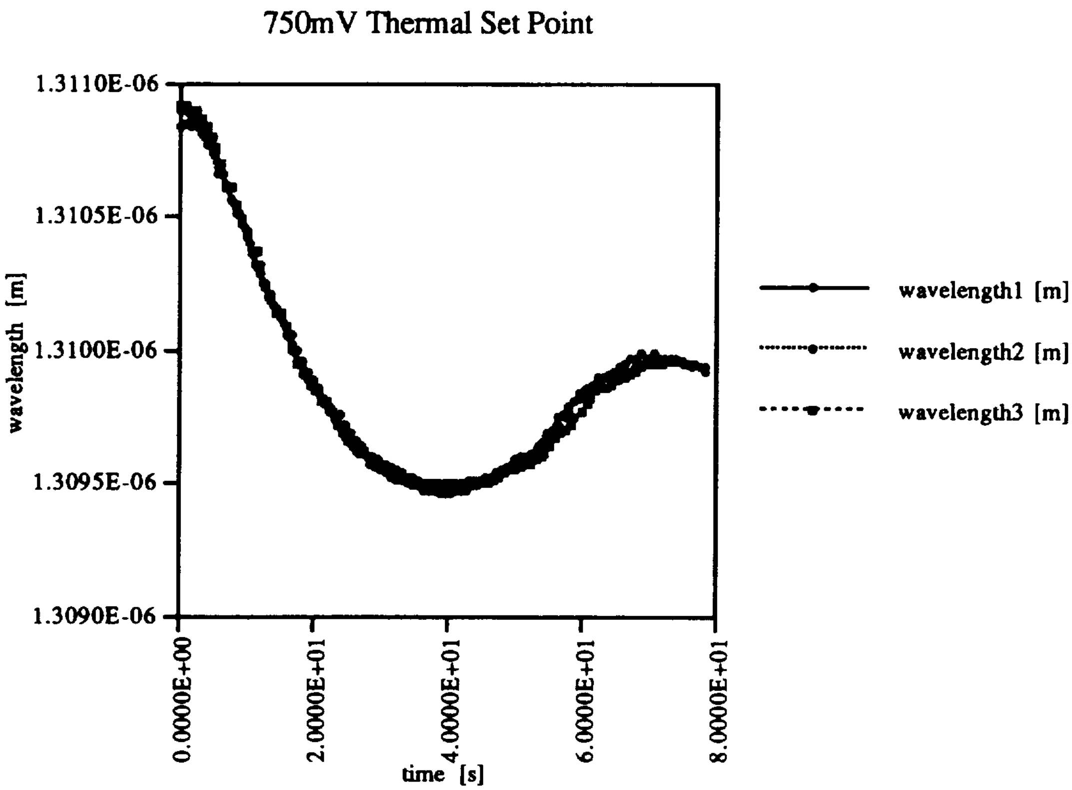
REFERENCES

1. C.G. Akins, G.M. Williams, and E.J. Freibele, "Contiguous Fiber Bragg Grating Arrays Produced On-Line During Fiber Draw", SPIE Proceedings - Smart Sensing, Processing, and Instrumentation, 14 - 16 Feb. 1994, Orlando Fla.

2. William W. Morey, Gary A. Ball, and Gerald Meltz, "Photoinduced Bragg Gratings in Optical Fibers", Optics and Photonics News, Feb. 1994.

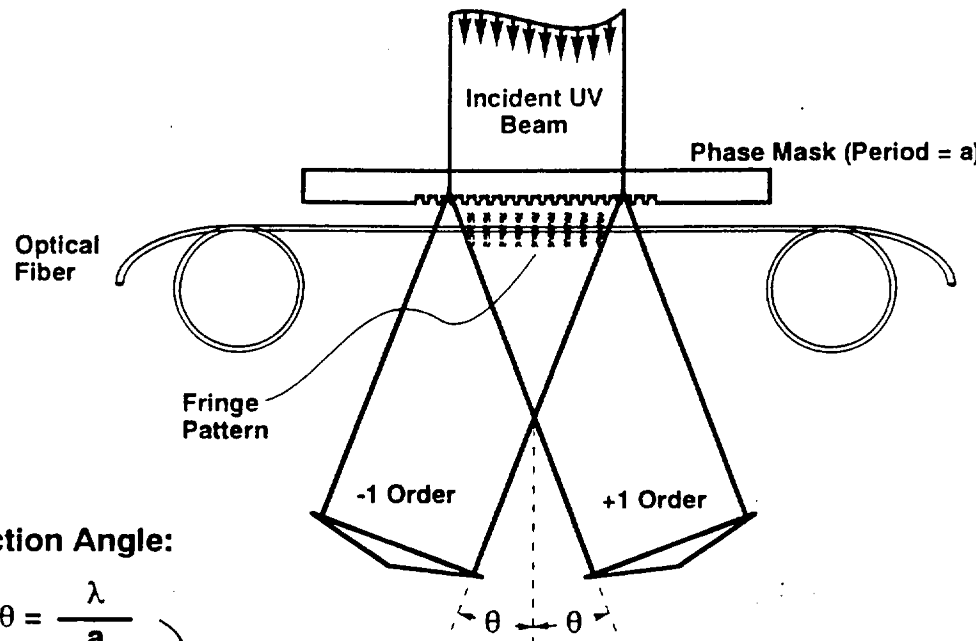


Calibration curve for the determination that a two second data accumulation time will be used using a 500mV thermal set point.



Calibration curve for the determination that a two second data accumulation time will be used using a 750mV thermal set point. Notice the non-linear response at the start of the signal accumulation. The actual linearity will be accumulated after a few milliseconds.

Writing Gratings in Optical Fibers with a Phase Mask

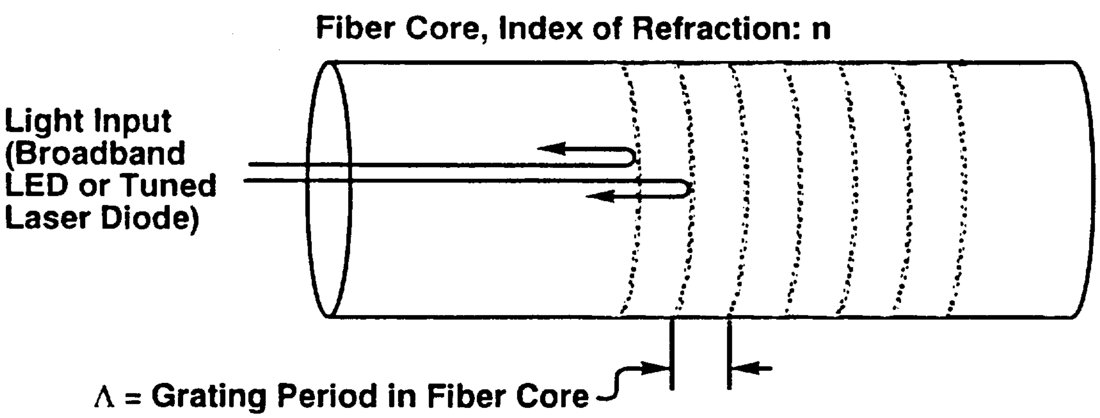


Diffraction Angle:

$$\sin\theta = \frac{\lambda}{a}$$

Fringe-to-Fringe Period: $L = \dfrac{\lambda}{2\sin\theta} = \dfrac{a}{2}$

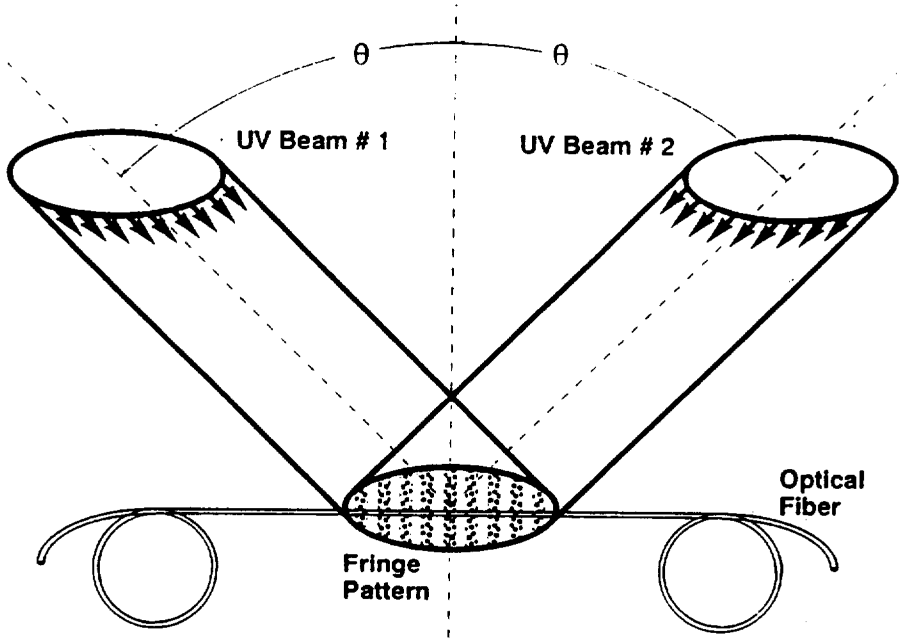
The Bragg Condition for an Intra-Core Fiber Grating



2nΛ = Optical path difference between light 'reflected' from adjacent 'lines' in the intra-core grating

The Bragg wavelength of the reflected signal: $\lambda_B = 2n\Lambda$

Bragg Gratings in Optical Fibers: Two Beam Interference



Fringe-to-Fringe Period: $L = \dfrac{\lambda}{2 \sin \theta} = \Lambda$

To Write a Grating at a Particular Bragg Wavelength

Phase Mask Method

$$a = \frac{\lambda_B}{n}$$

Holographic Method

$$\theta = \mathrm{Sin}^{-1}\left[\frac{n\lambda_W}{\lambda_B}\right]$$