The Development of Hands-on Fiber Optics Undergraduate Course

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Abstract — This paper outlines the development of a one credit undergraduate laboratory course to be taught concurrent with a lecture course. Students in this laboratory course learn about a variety of subjects pertinent to fiber optics and contemporary design techniques for communication systems and sensing within electrical engineering curriculum.

This laboratory course is designated exclusively to hands-on experience. The course is designed to cover a wide area of fiber optic basic theories and applications. It includes laboratory experiments introducing students to the following: basic knowledge, skills and manual dexterity needed for handling and testing fiber optic waveguides, characteristics of optical components, fiber optic communication systems, and fiber optic sensing systems.

1. INTRODUCTION

This paper describes the development of a one semester credit undergraduate laboratory course (Optical Fiber Laboratory) to be taught concurrent with the Optical Fiber Communications lecture course (Optical Fiber Communications). The project is supported by: 1. National Science Foundation (NSF) Instrumentation and laboratory Improvement (ILI) Grant DUE-9751368 " Fiber Optic Communications and Photonics Laboratory" (July 1997- June 1999); 2. over matching from the College of Engineering at South Dakota State University; 3. Electrical Engineering alumnus; and 4. equipment manufacturers.

The course is designed to cover a very broad area in fiber optics. This course is suitable to be taught in a smaller size program where limited number of courses is offered. However, in a larger program, the course could be divided into three separate laboratory courses; fiber optic characteristics and handling; fiber optic communication systems; and fiber optic sensing systems. Obviously, more material should be added then to fill-up the 15 weeks semester for the three laboratory courses.

2. MOTIVATION

The most recent model for optimization of learning, suggests that student interest, involvement, and retention are greatest for material studied in a practical framework with hands-on, integrated and inquiry experiences. Recent experience within engineering education indicates that this method is very effective. In most electrical engineering undergraduate curricula, hands-on model of learning is incorporated in many courses such as Networks, Electronics, Digital Systems, Power Systems, and Microprocessor Systems. However, this method of learning is seldomly implemented in teaching fiber optic communications courses where the material is highly abstract and theoretical. Hence, a fiber optics / photonics hands-on course is essential to keep students interested and involved in theoretical concepts taught in lecture.

As a typical engineering department, the Electrical Engineering Department at South Dakota State University offers several undergraduate courses under the communications option including a lecture course in fiber optic communications. However, this course suffers from the lack of hands-on experience. Due to this deficiency the students are:

1. Unable to prove, reinforce, and retain critical theoretical principles learned in class.
2. Deficient in certain specialized skills areas expected of him/her in industry and research.
3. Left without enough curiosity and eagerness to research, discover, and advance learning.

The introduction of a laboratory course such as the one outlined in this paper optimizes course learning by eliminating the deficiencies listed above.

3. COURSE OUTLINE

Each of the following eleven experiments will be performed in a single laboratory period of three hours. Students will write and submit a laboratory report which will be graded by the laboratory instructor. Four weeks out of the fifteen weeks semester are left open for instruction, reviewing, and testing. Laboratory experiments introduce students to the following:

1. Basic knowledge and skills needed for handling and testing optical fibers[1-2] (experiments 1-5).
2. Characteristics of optical components[2] (experiments 6-7).
3. Fiber optic communication systems[3-4] (experiments 8-9).
4. Fiber optic sensing systems[5-6] (experiments 10-11).

Brief description of objectives and procedures of these experiments are as follows:

Experiment 1: Introduction

Objectives: Review safety measures and theoretical concepts of optics and fiber optics.

Experiment 2: Fiber Geometry, Cleaving, Coupling and Inspection
Objectives:
1. Introduce fiber cleaving using a variety of cleavers.
2. Check the cleave using inspection microscope.
3. Test fiber to fiber coupling using mechanical splices.

Procedure: Cleave a multimode fiber with three different cleavers: Carbide Cleaver, Diamond Cleaver, and Electronic Cleaver; inspect the fiber cleave quality with Fiber Micro-Interferometer; splice the fiber using mechanical splices; estimate splice loss using a Power Meter.

Experiment 3: Numerical Aperture and Fiber Attenuation
Objectives:
1. Measure numerical aperture for multimode fiber.
2. Measure fiber attenuation per unit length.

Procedure: Measure the power accepted by two multimode fibers as a function of the incident angle of a plane wave laser beam and calculate the numerical aperture; measure the power received at the far end of a long spool of fiber, then, after cutting off a length of a fiber, calculate the attenuation per unit length (cutback method); find average, and deviation of all groups.

Experiment 4: Handling Single Mode Fiber
Objectives:
1. Couple light to single mode fiber.
2. Measure the effect of fiber bending (bending loss).
3. Observe the effects of angular and axial misalignment.
4. Splice a single mode fiber using a fusion splicer.

Procedure: Couple an HeNe laser to a single mode fiber using a microscope objective lens; measure the drop in far end received power as a function of bending radius; plot axial separation versus excess loss; plot angular offset versus excess loss; splice fiber using fusion splicer and measure splice loss, compare with other groups and calculate average and deviation.

Experiment 5: Properties of Single Mode Fiber (almost single mode)
Objectives: Measure the far-field power distribution of the fiber as a function of angle and fiber modes.
Procedure: Measure the power received by the detector as a function of the angular position of the fiber (far-field power distribution); observe irradiance pattern of some low order modes.

Experiment 6: Semiconductor Laser Diode Characterization
Objectives:
1. Plot laser's static input current versus output optical power (LD characteristics).
2. Examine laser's frequency versus current characteristics.
3. Observe modulation spectral broadening (FM chirp).
4. Measure laser's amplitude, phase and frequency noise.

Procedure: Plot the optical power collected by a power meter versus laser's driving current; notice the threshold current level as a function of the diode temperature; use a Michelson

interferometer to convert frequency variations into intensity variations; observe and measure laser's relative intensity noise and chirp using a Lightwave Signal Analyzer.

Experiment 7: Fiber Optic Communication Devices
Objectives:
1. Experiment with multi-mode bi-directional couplers.
2. Build a wavelength division multiplexer (WDM).

Procedure: Measure the splitting loss of a bi-directional coupler; observe reflection effects on coupled optical power; construct a two-channel wave division multiplexer using graded-index (GRIN) rod lenses and a wave length selective filter.

Experiment 8: Fiber Optic Communication System I
Objectives:
1. Build a noncoherent, intensity modulated optical fiber communication link.
2. Observe fiber dispersion as a function of signal's wavelength.
3. Use the principle of WDM to transmit two audio signals on one fiber.
4. Introduce the concept of cross talk.
5. Measure system losses and tabulate power budget.

Procedure: Connect an injection laser diode and light emitting diode to a WDM; measure the rise time for each wavelength with and without a multi-mode fiber spool of five km long; estimate fiber dispersion for each wave length; connect two audio sources to modulate the two light sources. Connect only one receiver and observe the cross talk; Measure the transmitted power at the laser's output and at the receiver's output and find link loss.

Experiment 9: Fiber Optic Communication System II
Objectives: Investigate source nonlinear distortions and clipping.
Procedure: Build a noncoherent, intensity modulated optical fiber communication link with two modulating tones. Measure the cross talk, as in Experiment 8, as a function of the optical modulation index, specially when the modulation index is sufficiently large that negative peaks of the input signal causes threshold clipping.

Experiment 10: Intensity Sensors
Objectives: Investigate examples of sensors which exploit the optical properties and light-guiding capabilities of multimode fibers.
Procedure: Construct and test the following: pressure sensors by using the photoelastic effect, microbend sensors by measuring extra bending loss.

Experiment 11: Interferometric Sensors
Objectives: Investigate examples of sensors which exploit the phase changes caused by a variety of physical parameters on the single mode fiber and Bragg Grating Fiber.
Procedure: Construct and test the following: temperature sensors by measuring the fringe displacement of Mach-Zehnder interferometer, and pressure sensors by measuring the wavelength change caused by the change of the index of refraction of Bragg fiber grating.

4. CONCLUSION

This paper described development of a one semester credit undergraduate fiber optic laboratory course to be taught at the Electrical Engineering Department, at South Dakota State University. The course is to be taught concurrent with the Optical Fiber Communications lecture course. The course is designed to cover a very broad area in fiber optic, hence, it is suitable to be taught in a smaller size program where the number of taught courses is limited. Students in this laboratory course learn about a variety of subjects pertinent to fiber optic characteristics, handling, communication systems and sensing.

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Biographical Information

ALFRED S. ANDRAWIS, received his Ph. D degree from Virginia Polytechnic and State University in December 1991 in electrical engineering. At present, he is teaching, as an Associate Professor, several courses in Communications, and Fiber Optic Communications at South Dakota State University. For five congestive years he received NASA/ASEE Summer Faculty Fellowship Award to conduct research with several NASA centers in Communications, Fiber-Optic Networks, and Bragg Grating Fiber applications.