Center for Integrated Access Networks (CIAN) Undergraduate Research Fellowship Proposal:

Swept-Wavelength System

Jasmine Roberts
Electrical Engineering, *Columbia University*

Nominated by: Keren Bergman, Professor and Dept. Chair of Electrical Engineering, *Columbia University*
Supervisor: Atiyah Ahsan Ph.D. Candidate*, Columbia University*

Submitted to—
Center for Integrated Access Networks
National Science Foundation, University of Arizona

Contents

Abstract

With the expanding intricacy of WDM and DWDM network systems, it has become increasingly critical to fully characterize the wavelength-dependent optical properties of both broadband and narrowband network components

Properties such as wavelength flatness and polarization-dependent loss can negatively affect network systems. For narrow-band devices, these measurements are vital in order to optimize system performance.

When using a standard step-and-measure system (tunable laser, the device under test (DUT), and power meters)— data from both outputs require over 2 hours to gather. However, with the fast sweep system, measurements can be performed in less than one second. Because of the significant deduction in measurement times, the fast sweep method is ideally suited for time-consuming measurements of narrowband and polarization sensitive devices.

Technical Procedure

Constructing the System

Producing a fast sweep system requires nearly the same equipment as the step-and-measure system: a tunable laser source, the device under test, power sensors, and a data acquisition system. It differs from the step-and-measure system only in the specific requirements of the source and the detectors. In the fast sweep system, the wavelength of the laser source is swept continuously at a constant rate while the output is recorded, providing a high-resolution spectral picture at the speed—fast enough to observe changes as a component is being adjusted. Typical system setups measure the transmission, reflection, and polarization effects of a device as a function of wavelength are shown in the figure below:

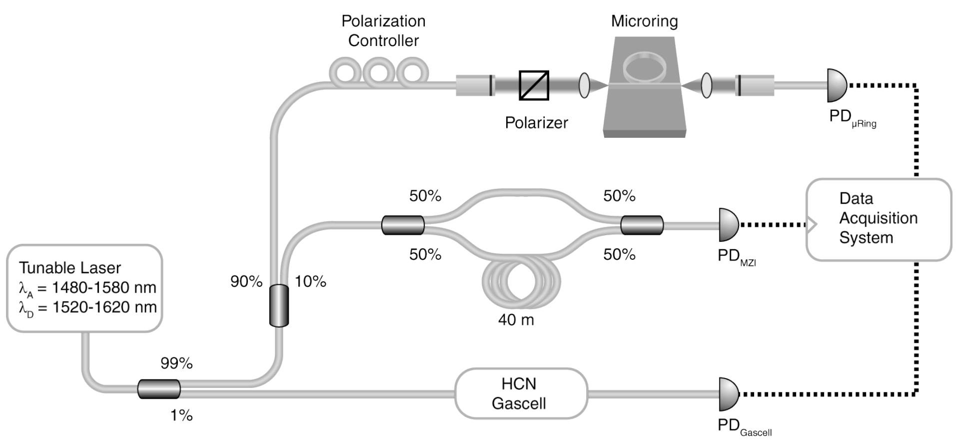

Figure 1: Swept-Wavelength (Fast Sweep) System

The tunable laser source: The most vital component in a swept-wavelength setup is the tunable laser source. An important feature of the tunable source is a trigger signal. In a sweep, an electrical trigger signal alerts the data-acquisition system to begin taking data. The trigger accuracy in conjunction with the laser's deviation from linearity, determines the system's wavelength accuracy. Scanning wavelength repeatability is vital for measurements in real time. Any inaccuracy causes the data to shift with respect to wavelength from scan to scan, and determining real-time changes from spurious shifts will be difficult.

In the setup for measuring insertion loss or filter rejection, the output of the reference detector is used to normalize any intensity fluctuations from the laser and any wavelength-dependent sensitivity variations in the detector. In the swept-wavelength system, the laser is programmed to sweep over the wavelength range of interest while providing an electrical wavelength trigger. In the system, the laser sweeps the wavelength with respect to time, so the x-axis on the oscilloscope corresponds to wavelength.

The last consideration for the tunable source is the stability of the output power. There are two aspects: power flatness within the scan and power repeatability from scan to scan. Power flatness is defined as how constant the output power is during a single scanned wavelength. Power repeatability between scans measures the stability of output power as the laser makes many wavelength scans. This is especially important when considering real time because any changes in scanning power can seem like changes to the device rather than fluctuations from the laser. The next required component in the swept-wavelength system, is the power meter or power meters if monitoring multiple channels. Recording and storing data is best done using a data-acquisition system consisting of a data-acquisition board followed by a PC. The HCN gas cell is used to find the exact wavelength corresponding to a peak or dip. Gas cell has dips/ peaks at specific wavelengths. By looking at the data from the DAQ, the time stamp can be matched on a peak/dip to a specific wavelength and this helps with accuracy of transforming your power versus time data to power versus wavelength curve that is needed.

Conducting Measurements

An oscilloscope is used for relative measurements, real-time, and high-resolution data. The laser is programmed to sweep over the wavelength range of interest. The optical output is sent to the device under test (DUT) and then to a detector. The output from the detector is displayed on an oscilloscope, triggered using the laser's wavelength-trigger output. The stability of the wavelength trigger and the repeatability of the laser scan ensure that motion seen on the oscilloscope is due to the spectral change of the DUT.

A computer stores and normalizes data by gathering the data as the laser sweeps over the wavelength range of interest. In this case the electrical trigger is used to notify the computer to begin taking data

Interpreting the Data

Translating from time to wavelength, the laser sweeps the wavelength with respect to time; therefore, the x-axis on the oscilloscope trace corresponds to wavelength. The following equation can be used:

$$\lambda = \lambda_0 + v\Delta t$$

Wavelength=Initial Wavelength + (Scan speed)(Elapsed time of scan)

For increased wavelength accuracy, an optical reference is used a trigger source rather than the supplied electrical trigger. In this setup, a portion of the output laser intensity is diverted, passed through the absorption cell, and detected. The output is sent to one of the inputs of the data acquisition system.

By using a typical minimum-detection algorithm, one of the absorption minima can be used as the reference trigger.

Detecting the sweep linearity allows for improvements; sweep linearity consists of two factors: the best fit average speed, and any momentary deviations from the average speed. Both can be measured by measuring the transmission through an interferometer (étalon) while making the wavelength measurements on the DUT. An effective and simple étalon is a non-angled short length of fiber between two other APC fibers—one coming from the laser source and the other going to the detection system. As the laser wavelength is swept, the transmission through the etalon as a function of wavelength can be expressed as: where *R* is the reflectivity of the surfaces, *n* is the index of refraction, *l* is the length of the fiber, and λ is the wavelength.

The transmission is at a maximum whenever $\frac{2nl}{\lambda}$ is an integer. Thus, by detecting the peak and measuring the time interval between peaks, the average peak-to-peak velocity can be determined. In addition, the actual peaks are frequency markers that determine the momentary relative wavelength change. Using a étalon measures the average speed as well as the relative wavelength change, and therefore the deviations from linearity.

Project Management

This range for completion of this project is approximately 15 weeks from the targeted end date is April 29, 2013. Work will be performed 10 hours weekly.

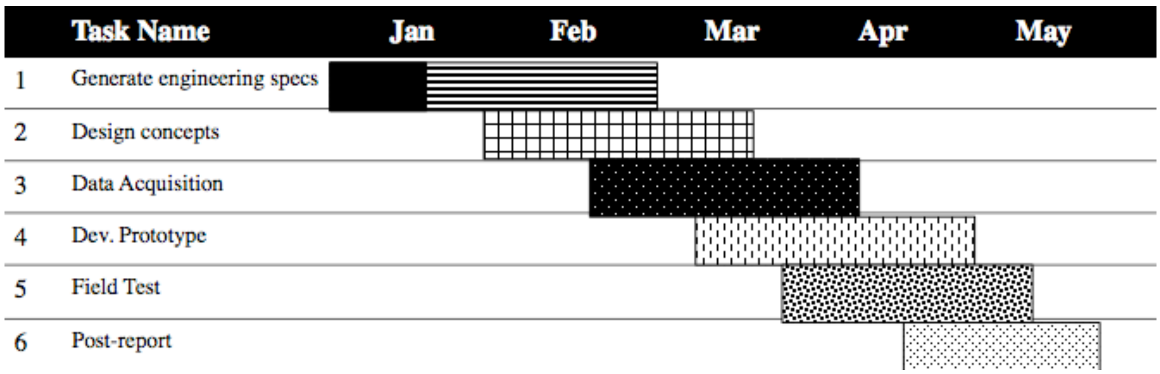

Figure 2: Gantt chart for project. Solid bars indicate portions of tasks that have been accomplished.

Communication and Coordination with Sponsor

Communication with the Center for Integrated Access Lab will be conducted through the Lightwave Research Laboratory at Columbia University. Bimonthly, hours will be recorded and into an Excel® spreadsheet in addition to Gantt chart updates to be sent and reviewed by the sponsor.

Personal Statement

I have been interested in research since the beginning of my undergraduate engineering program. I always believed that research projects are an excellent method for developing analytical skills and enhancing knowledge of a particular field and this has inspired to participate in several/various research projects. My interest in research has been the prime motivation for continuing to graduate study. Researching gives the foundation and fundamentals from the previous knowledge, and the opportunity for re-examination to build towards future advances.

I intend to pursue a graduate degree in the field of applied optical electrical engineering and become a professional research scientist. The Center for Integrated Access Networks (CIAN) fellowship provides a productive research platform for the students as well as gives an effective learning experience and it will enable me to acquire the research and publication skill I need to succeed in my career goals. Additionally, it equips with advanced research technologies regarding optical engineering, which facilitates effectively the learning experience I wish to obtain.

I believe that the swept-wavelength system that I will construct for CIAN is well suited to my research skills, which I aim to develop further while pursuing the research fellowship program. I will develop effective research skills in different aspects of electrical engineering including networking and optimization. Therefore, I have found CIAN research fellowship program to be a productive source of developing research skills as well as enhancing a vast knowledge regarding electrical engineering modules to be used for further study.

I have an academic background in this field, consisting of various electrical engineering coursework like optics and electromagnetics, along with working on many engineering freelance projects. Working on these self-driven research projects has compelled me to seek broader research opportunities. After completing laboratory work on solid-state devices, microwaves and fiber optics, I feel that I have become more capable in understanding and conceptualizing different modules as they relate specifically to optics. Overall, I enjoyed completing this lab work, as these reports gave practical learning or insights regarding diverse concepts.

Currently, CIAN is working on transforming the expensive optoelectronic technologies to be affordable as well as integrating optoelectronic subsystems, which would reveal optical network infrastructure as well as integrated functionalities in order to provide heterogeneous services. Particularly, all these research projects highly inspire me to be the part of CIAN, as by working on these research projects I would develop research capabilities as well as advanced research knowledge regarding optical electrical engineering modules.

Overall, it would be a great honor to be a part of CIAN research fellowship program at the Light wave Research Laboratory at Columbia University. Further, I firmly believe that excellence of CIAN along with my motivation as well as competencies will assist me in becoming a competent researcher. While working on different research projects at electrical engineering research center at Columbia University, I would be more capable to develop research skills as well as gain practical learning experience. Similarly, I believe that the Center for Integrated Access Networks will help in advancing my research skills to use for further study in graduate school; I am motivated to put my efforts in becoming a competent part of an engineering research center such as CIAN.