Session T3B1

Online Laboratory for Optical Circuits Courses: Effective Concept Mapping

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Abstract

There are multiple challenges involved in teaching laboratories online. In this paper, we address the fundamental issue of deciding what laboratory material can be well presented online. This work is part of an ongoing joint effort of the University of Houston and the University of Colorado to develop remotely-controlled laboratory experiments for optical circuits courses, an effort that was first described in a paper presented at the 2005 ASEE Annual Meeting[1]. In this paper, we will discuss the design and implementation of two laboratories, one covering the characterization of light emitting diodes and one covering the characterization of laser diodes. The discussion includes our design criteria. We then will proceed to present the details of an assessment program we constructed to determine how effectively our chosen material serves our purposes.

Introduction

Online education is gaining widespread interest mainly because of the flexibility it offers in terms of scheduling, effective teaching time usage and learning pace. On the other hand, inexpensive broadband services allows for new dimensions in online learning whether they be real time interactive video conferencing of class material or asynchronously accessed and controlled streamed lecture material, laboratory instructional videos and even laboratory simulations that can be performed by the student. Hands–on laboratory is one of the main components of engineering education that needs special attention and consideration for an e-learning environment. An online laboratory experiment using simulation as the only tool lacks two main interactions of the active hands-on experience: the equipment and the instructor.

One of the challenges of online laboratory development is how a set of fundamental concepts can effectively be addressed in on-line laboratory. The purpose of this paper is to present a remotely–controlled laboratory experiment that will help develop hands–on skills while contributing towards understanding concept mapping to an online hands-on experiment. This paper presents implementations and preliminary results of optical source characterization namely light emitting diode (LED) and laser diode (LD). The laboratory uses a combination of simulation and an actual remotely-controlled experiment. Simulation is implemented using VPI Transmission Maker software; while the experiment is developed using LabView based on a previous model by the authors[1]. Students only need to download a free Runtime Engine to access the programs on a serving computer. A webcam is used to view the setup to have a feel of what is being controlled.

This is a joint effort between the University of Houston and the University of Colorado towards the development of an online laboratory for optical communication circuits courses. Presently, the lecture and laboratory courses are taught at the University of Houston while the collaborators at the University of Colorado will be assessing and evaluating the laboratories. In the future both laboratory and lecture courses will be offered at both universities within the e-learning environment. This distributed teaching environment will allow different institutions to share expertise and expensive equipment. The purpose of the laboratories is both to develop the hands-on skills that can be obtained in the online setting, those that are common to most of modern day automated experimentation as well as to be expose the student to a set of concepts necessary to understand optical circuits. Concepts to be presented need to parsed and presented with care taken to use the best practices of the remote controlled environment.

Overview

Online education has been gaining momentum for many years, in great degree due to the industrial need for training[2]. Broadband access, which provides high bandwidth access to the Internet, is beginning to have an effect on the content of such materials[2,3]. There seems to be consensus that video streaming is preferable to simply static placement of material on a website. The efficacy of live streaming (large scale teleconferencing) versus asynchronously accessible streamed video on learning seems to be an open question. Although evidence presented in [2] is anecdotal, there are arguments for posting streaming pre–recorded video whose playback can be controlled by the viewing learner. There is added content in live streamed video with real time feedback when compared with a stored video presentation, even when the stored version has a playback control. But it is not hard to imagine that highly motivated students may respond more positively to controllably streamed materials available at their convenience than to a teleconference which must take place at a fixed time.

The National Instruments website[4] mentions one remote laboratory effort among three LabView related classroom efforts that National Instruments deems noteworthy. The laboratory was an optics related one demonstrated at Stanford for the first time in 1998[5]. There seem to be no peer reviewed publications related to this demonstration, and, although there was a company involved in commercializing the materials, the website of the company contains no further information on the distance learning materials beyond that in the National Instruments brochure and the internal Stanford document. A group of researchers from Norway and the United States published results of a joint effort to implement electrical circuits experiments in 1999[6]. Several other researchers have published related work in other universities[7]. Of these efforts, the only one related in any way to optics does not appear in peer reviewed publications[5], but it appears from the unpublished advertisements that the subject material there does not relate to optical circuits either. Although the technology necessary to put an optical communication circuits laboratory online does seem to be available, there seems to be no model for the presentation of online material, per se.

Experiment design for remote control laboratory for optical circuits

Designing an experiment that students do in a laboratory room does not require thinking about the mechanical manipulation that student do to change part of the experiment to compare concepts or take data points. This becomes different when designing remotely controlled experiment for online laboratory. The experiment should have enough controllable parameters so that enough concepts can be dealt with in the same experiment. If the experiment is too simple, students will be bored and loose their enthusiasm. Therefore it is very important that several concepts can be mapped into one experiment set up to get the student conduct the experiment in one setting and come up with comparisons and analyses. This is one of the main challenges in online experiment design.

Here we present two experiments combined in one set up for optical source characterization; namely light emitting diode (LED) and laser diode (LD). The student needs to characterize the spectrum of these sources using optical spectrum analyzer (OSA) and compare them. To be able to draw conclusions, students need to have the capability to characterize both sources in the same setting. OSA is very expensive test equipment and has only one input channel. For students to switch back and forth between sources (without manual intervention and as if he/she is in real lab) and read the results from the OSA, an optical switch with GPIB interface is utilized to implement this flexibility. Figure 1 shows the experiment design for optical source characterization. To complement the experimental part a pre-lab simulations is used for student to have a proper preparation to what to expect during the experiments.

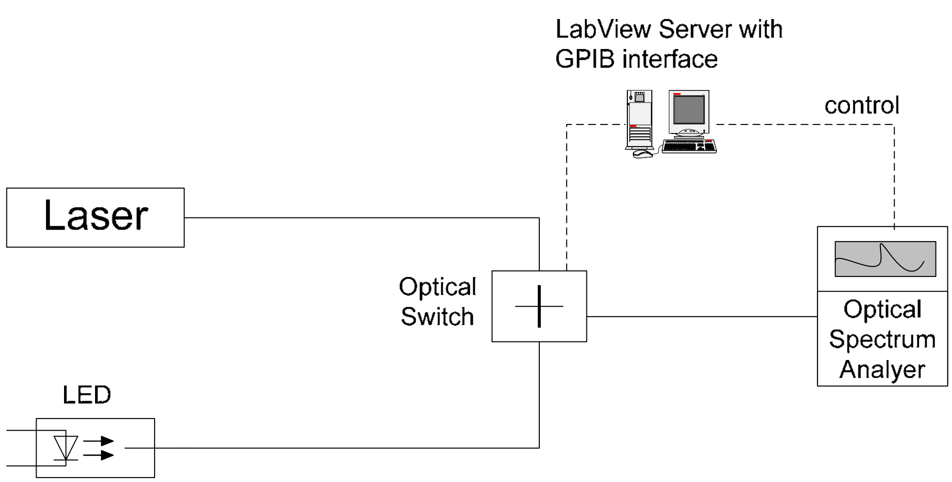


Figure 1: Optical source experimental setup

During the Fall 2005 semester, these experiments were implemented in ELET 4398: Optical circuits. The material accompanying the experiments consists of two components: simulations and interactive remotely controlled experiments. The simulation is conducted as a prelab and allows students to study optical sources using simulation software. This will allow them to play with multiple parameters of a model and analyze the effect of those parameters. Even though there is no actual experiment to work with at this phase, we expect that student will develop preliminary understanding the devices under test. Also, prelab will prepare student to investigate on issues related to the lab and do the homework before performing the remote lab. The interactive remotely controlled laboratories involve the real time control of equipment on an actual lab bench. Students configure real equipment and collect the data and analyze it.

Simulations

Optical source characterization is an important concept in fiber optic communication system design. A simulation model was developed, using VPI transmission maker software, to give students the ability to experiment first hand with various source types (LED, LD) and vary parameters. It allows us to simulate optical components and systems using setting similar to real experiments. The simulation tool that student will be using is shown in Figure 2. The bottom right quadrant of the tool shows the parameters that student can vary and study their effect. Here student have the ability to vary the current supplied to the source and therefore draw the current versus optical power curve. The outputs of the simulation are power level of and the spectrum of the source. Note this simulation model mimics closely a real experiment and provide student with a sense of dealing with real equipment.

The simulation is distributed to students using .dds file generated by the VPI transmission make simulator. Students need to download the freeware VPIplayer and run the simulation. After running the simulation the results are collected and analyzed. Figure 3 shows typical results of a laser source. Student runs multiple instances to collect the power level and draw the curve that displays the current versus the optical power level.

Remotely Controlled Experiments

The remotely controlled experiment developed for the ELET 3325 uses a remotely controlled Optical Spectrum Analyzer (OSA) and optical switch. The goal of the experiment is to use the OSA to measure the spectrum of the LD and LED. The OSA and the optical switch are connected to a PC via the general purpose interface bus (GPIB) IEEE 488.2 on the back of the instrument. Remote operation of the instrument is accomplished with a virtual instrument panel written in LabView 7.0 that is accessed by the students over the internet using LabView 7.0 web server application software. Figure 4 show the physical set up of the experiment while Figure 5 shows the virtual instrument that student sees when doing the experiment remotely.

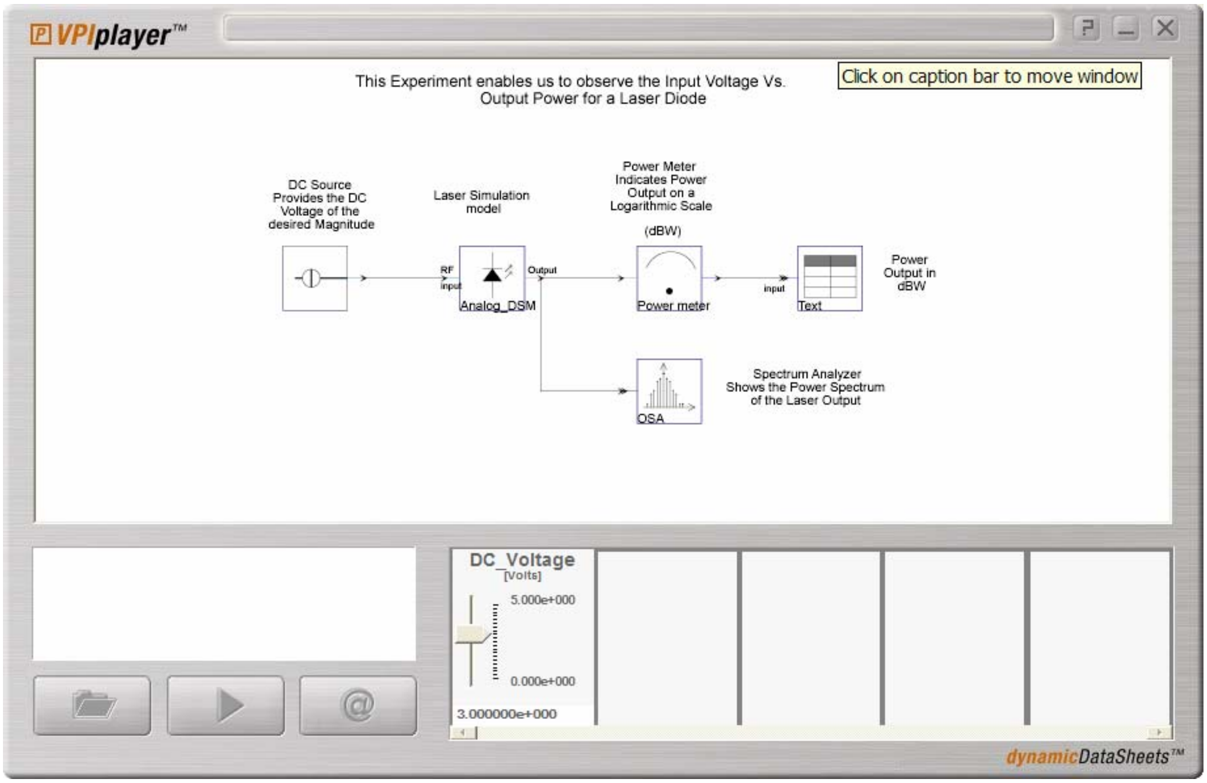
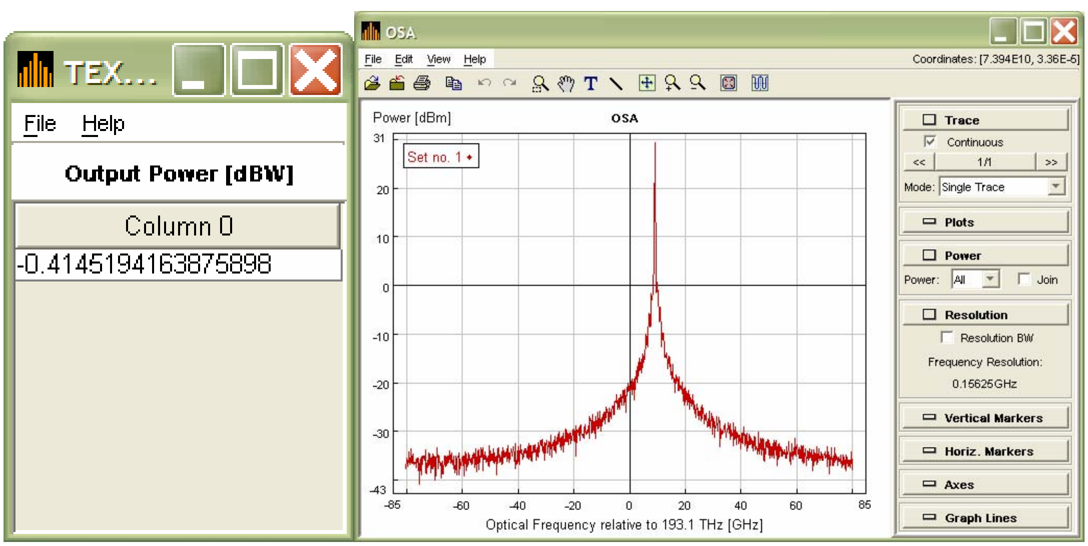


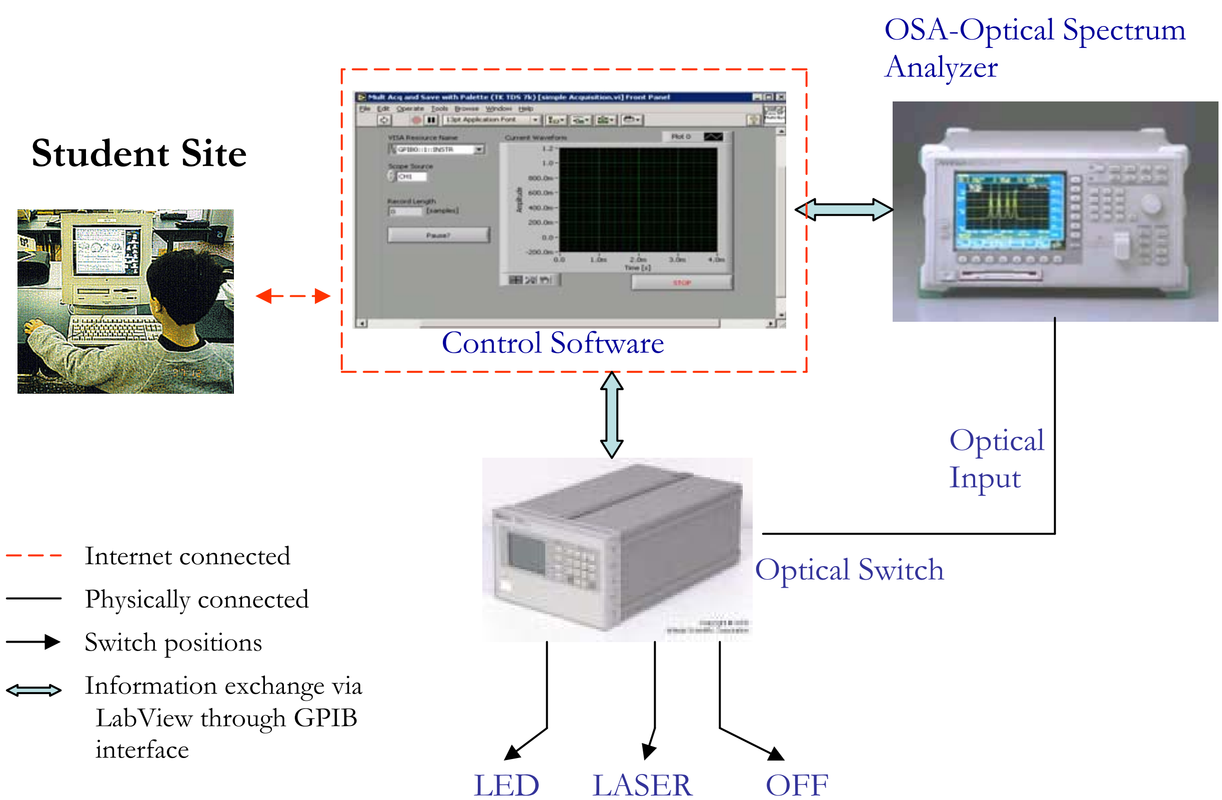
Figure 2: VPI Player simulation software illustrating the set up to simulate an LD set up. Students have the ability to change the power supply voltage/current fed to the LD and measure the power level of the source. Spectrum is also measured using virtual OSA.



(a) **(b)**

Figure 3: The output power (a) and the spectrum (b) of the LED after the simulation is run.

Along with the virtual OSA instrument panel accessed over the Internet, the students can also view a live video feed from the lab to observe the changes in the actual OSA display as measurements are made. While the changes in the virtual instrument panel display are the same as those on the actual OSA, the virtual instrument does not implement all the buttons in the real OSA. Rather, only the necessary measurements are communicated directly to virtual experiment for students to note. Observing the changes in the real instrument panel, using the webcam, give the user assurance that changes in the measurement parameters and signal on the virtual instrument panel correspond to changes on the actual instrument. In addition, the live video can provides a view of all the set up as some of the equipment are not controlled by students. This will give students confident about their measurement as well as have an idea of the physical set up of the experiment.



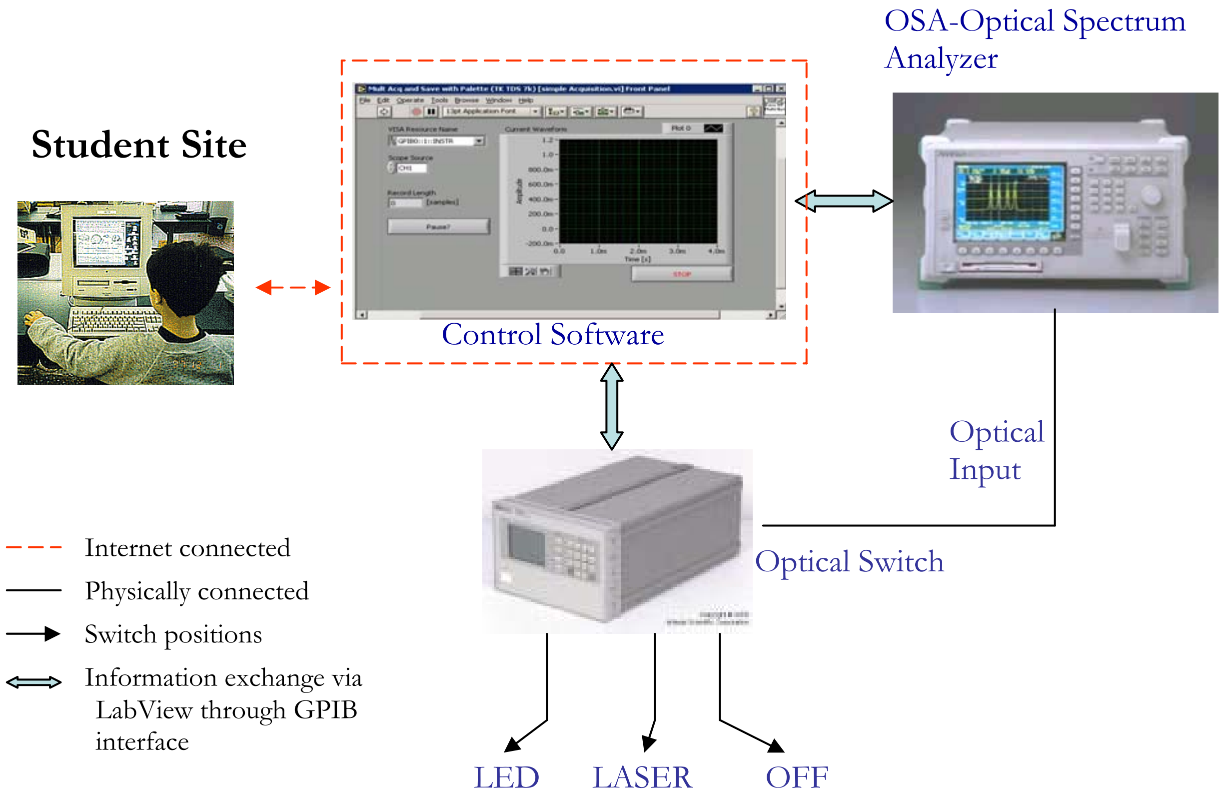


Figure 4: Physical setup.

The video feed of the webcam is generated directly from the webcam. The webcam has it own IP address and provide login name and password for security reasons. This feature is very practical since it is fast and save the use of PC resources to connect a camcorder. The video is then sent for distribution over the internet directly from the webcam.

Student Instructor Interaction

The technological advances with the test and measurement equipments allowed the manufacturing facilities at various production lines to have a remote monitoring and control over the processes. This e-learning project is in a way similar to the case where a factory may be isolated from human control over the production. In this respect, we would like to minimize the student-instructor interaction in order to have a close-to-real-life experience for students' future careers. However, educational goals will not be achieved without the proper learning environment. Therefore, we included a camera monitoring for both the instructor-student interaction and the lab test and measurement control environment. We will include an objective committee from industry professionals to assess the learning outcomes of this lab structure during our pilot labs.

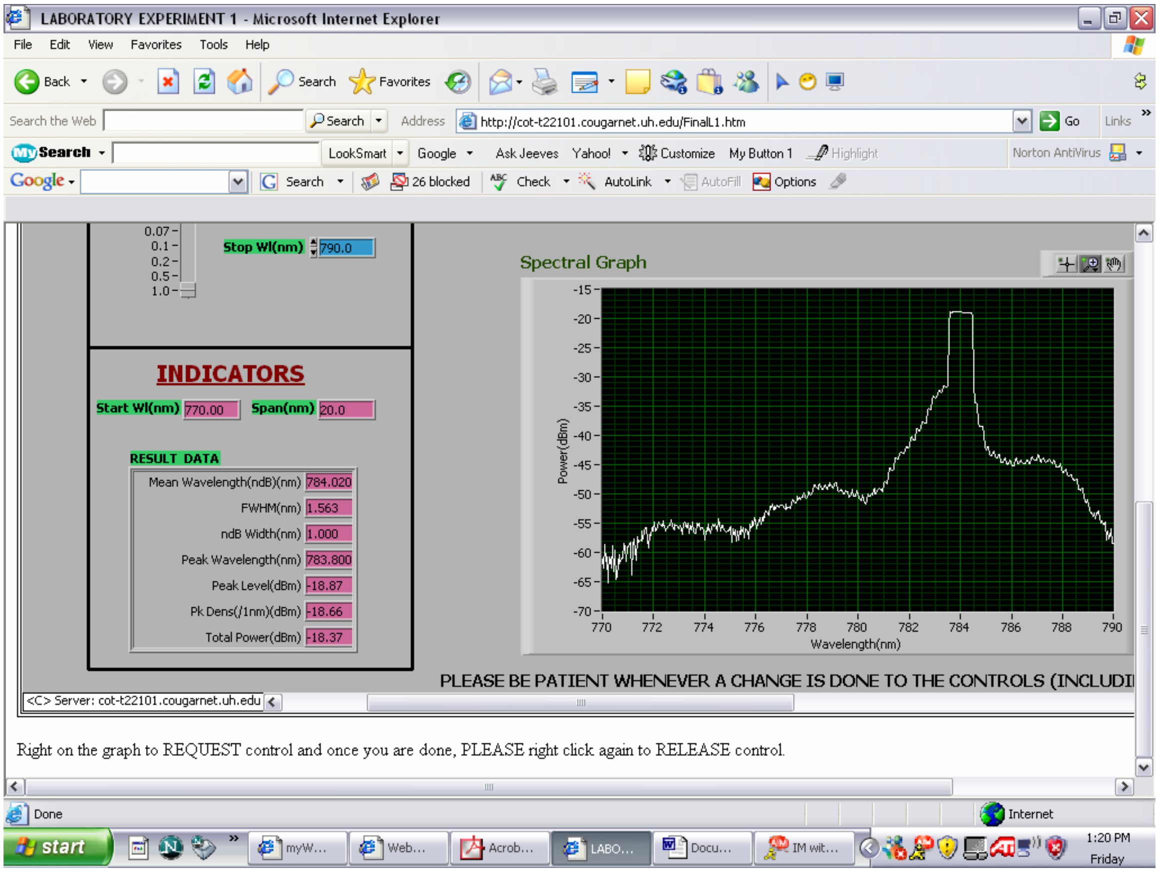


Figure 5: OSA virtual instrument front panel with readings illustrating the measurement the spectrum of the Laser diode.

Student Performance Metrics and Assessment

The students will have full control over the test and measurement equipment. These controls will allow them to measure and take note of the results of their measurements as well as their observations on the experiment. Since there is an electronic environment with printing and data processing capabilities, there will be real-time processing opportunities. All data processing and measurements will be required in the student reports. These reports can be submitted electronically. Report grading and online timed exams and quizzes will be implemented to assess student progress and understanding of the subject material.

Assessment of distance learning courses is a challenging task. It is hard for the professor to get a feel of who is following the experiment correctly and who is not. In addition to laboratory report grading and exams a direct comparison of the remote students and the on-site student may be implemented. This will require remote and on-site students to take a common exam that include theoretical as well as experimental work related to the experiment. Statistical analysis can be drawn from the results to assess the learning experience of remote student and compare them to on-site students. Development of assessment tools that provide a reliable feedback about student learning capabilities is important to distance learning and is a relevant line of research.

The authors collected students' opinions on the remotely controlled laboratories during Fall 2005 pilot test at the University of Houston. The survey asked questions related to improving the understanding of concepts developed in the laboratory, confidence in doing the on-line laboratory, and the confidence in doing the lab using the webcam. About %83.3 of students felt that the lab improved their understanding of the LED and LD characteristics. Also, %83.4 of students felt that remote laboratories gave them similar confidence compared to in-lab hands on experiences. And about %55.5 of students felt that the webcam had positive impact on their confidence in controlling the labs while %45.5 of students were neutral.

Conclusions and Future Implementations

The electronic environment will enable a variety of experiments to be implemented. Updates of these experiments will be easily developed over the core experiments with records of older experiments available for future classes. This is an ongoing effort; we will provide more experiments with student assessment feedback and analysis. Laboratory distance education opens new challenges such as student instructor interaction and development of assessment strategies that provide reliable feedback about student learning capabilities.

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References

[1] E. McKenna, R. Direen, F. Barnes, D. Gurkan, A. Mickelson, and D. Benhaddou, "E-learning Environmental Design of a Distributed Online Laboratory for Optical Circuits Courses," Proceedings of the ASEE Annual Conference, Portland, OR, May 2005.

[2] P. Hernandez-Ramos, D. Alexander, A. Belous and J. Behrens, Changing the way we learn: How Cisco Systems is doing it, International Workshop on Advanced Learning Technologies 2000, 177-179 (2000).

[3] E. Maga~na, and D. Morat¶o, Internet Technologies course with combined professor and on-line contents methodology, Tenth International Conference on Telecommunications, 1756-1761 (2003).

[4] National Instruments, Distance-learning remote laboratories using LabVIEW, web document of Naitonal Instruments (2002).

[5] L. Hesselink, D. Rizal and E. Bjornson, CyberLab: Remote access to laboratories throughout the world-wide-web, Stanford University document (1999).

[6] H. Shen, Z. Xu, B. Dalager, V. Kristiansen, Â. Str¿m, M. S. Shur, T. A. Fjeldly, J-Q. LÄu, and T. Ytterdal, Conducting laboratory experiments over the internet, IEEE trans. Education 42, 180-185 (1999).

J. O. Strandman, R. Berntzen, T. A. Fjeldly, Y. Ytterdal, and M. S. Shur, LAB on-WEB: Performing device characterization via Internet using modern web technology, Fourth International Conference on Devices, Circuits and Systems, Aruba, April 17-19 (2002) 1022-1--1022-6.

C. Wul®, T. Ytterdal, T. A. S½ther, A. Skjelvan, T. A. Fjeldly, and M. S. Shur, Next generation Laboratory-A solution for remote characterization of analog integrated circuits, Fourth International Conference on Devices, Circuits and Systems, Aruba, April 17-19, (2002), 1024-1--1024-4.

[7] G. Tait and N. Chao, Hands-on remote laboratory for freshman engineering education, ASEE/IEEE Frontiers in Education Conference T3 R-7 Boulder, CO (November 2003).

B. A. Galwas and R. J. Rak, Virtual laboratory- A future part of the new web-based model of undergraduate engineering studies developed by Warsaw University of Technology, Joint IMEKO TC-1 & XXXIV MKM Conference 2002.

D. Z. Deniz, A. Bulancak and G. Ä Ozcan, A novel approach to remote laboratories, ASEE/IEEE Frontiers in Education Conference T3 R-8-T3 R-12, Boulder, CO (November 2003).

A. Ferrero, S. Salicone, C. Bonora and M. Parmagiani, ReMLab: A java-based remote, didactic measurement laboratory, IEEE trans. Instrumentation and Measurement 52, 710-715 (2003).

M. Casini, D. Prattichizzo and A. Vicino, The automatic control telelab: a user-friendly interface for distance learning, IEEE trans. Education 46, 252-257 (2003).

T. Ostermann, C. Lackner, R. Koessel, R. Hagelauer, K. Beer, L. Krahn, H. T. Mammen, W. John, A. Sauer, P. Schwarz, G. Elst and M. Pistauer, LIMA: The new e-learning platform for microelectronics applications, IEEE International Conference on Microelectronics Systems Education (2003).

K. C. Chu, Development of a web-based teaching system for engineering education, Engineering Science and Education Journal, June 1999, 115-118.

T. Kikuchi, S. Fukuda, A. Fukuzaki, K. Nagaoka, K. Tanaka, T. Kenjo, and D. A. Harris, DVTS-based remote laboartoory across the Paci¯c over the Gigabit network, IEEE Trans. Education 47, 26-32 (2004).

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