Measuring the Speed of Light in an Optical Fiber

Integrating Experimentation and Instrumentation

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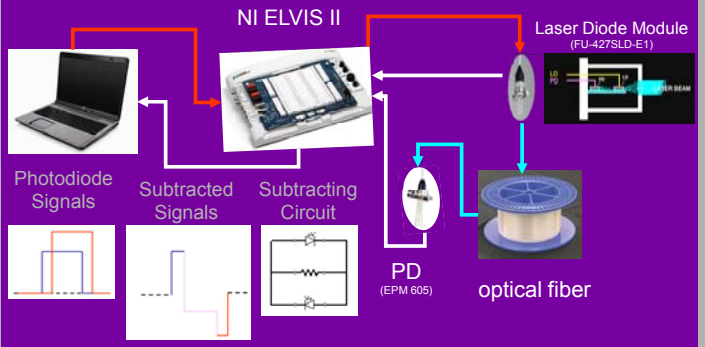
1. Introduction

Successful experimental physicists must understand the conceptual basis of experiments and the techniques of modern instrumentation, data collection and analysis. Through new capstone projects at Kansas State University, students in an electronics course, Physical Measurements and Instrumentation (PMI), apply their knowledge of electronics, instrumentation and LabVIEW to experiments from previous courses. This allows students to revisit the physics of earlier experiments and to solve real-world problems associated with experimental control and data acquisition. This speed of light measurement is one example of these capstone projects at Kansas State University.

2. Experiment Set-up

- Using the computer interface, a square wave signal from the NI ELVIS board is sent to a laser diode which produces a pulse of light.
- A photodiode adjacent to the laser diode receives a small fraction of the light pulse and sends a digital pulse to NI ELVIS.
- The rest of the light is sent through ~ 2 km of a single-mode telecommunication grade optical fiber and detected by another photodiode.



Subtracting the two signals enabled the measurement to be done on a single channel which improved the sampling rate from 0.5 MS/s to ~ 1.25 MS/s

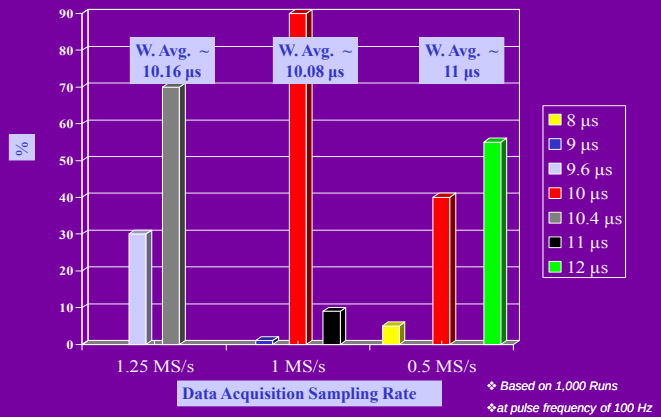
3. Calculation

- LabVIEW Programming is used to find the time difference between the two photodiode pulses.
- This allows the calculation of speed of light in the optical fiber and further analysis of the obtained results.

4. Results and Discussion

- Through LabVIEW the time difference between the two photodiode pulses was found to be ~ 10.16 µs (Weighted average at the maximum sampling rate of 1.25 MS/s).
- A digital oscilloscope (Tektronix TDS 210) was also used and a time difference of ~ 10.05 µs was found.
- Through LabVIEW the speed of light in the optical fiber is calculated to be ~ 2.054 x 10^8 m/s corresponding to a refractive index of n ≈ 1.4606 which is a typical value.

➢ The Measured time duration is more scattered at a lower sampling rate



	LabVIEW & NI ELVIS	O-Scope
Sampling rate (Max. Specified)	1.25 M Samples/sec.	1 G Samples/sec.
Time Resolution	~ 800 ns	~ 1 ns
Advantages	• Automates experiment thus making data acquisition and analysis easier and faster. • Provides students an opportunity to apply their electronics knowledge.	• Higher sampling rate and thus higher precision and accuracy

5. Expected Student Outcomes

This capstone project offers students in an electronics course an excellent opportunity to :

- Learn or revisit their knowledge of lasers and photo-diodes.
- Build hardware on the NI ELVIS prototyping board.
- Write a LabVIEW program to record a series of measurements and do statics on their results.
- Access uncertainty in the instrumentation and understand how that affects their measurement.
- See how analog-to-digital conversion limits the resolution of digitization.
- Explore other timing techniques like the Schmidt triggers, counter timers, etc.

6. Additional Capstone Projects

Below are other capstone projects under development:

- Photoelectric Effect
- Frank-Hertz Experiment
- X-Ray Spectrometry
- Saturated Absorption
- Mössbauer

7. Summary

Capstone projects in the PMI course provide a context in which students revisit previously studied experiments and design electronic instrumentation and analysis software using LabVIEW and NI ELVIS.

8. Future Work

- Integrate this speed of light capstone project with even more data acquisition techniques like sample & hold, counter timers, etc.
- Complete other capstone projects.
- Carry out a study to find out exactly how much of the expected goals the students attain and what else, if anything, can be done to improve the students' outcomes.

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