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DIDACTIC CONSTRUCTION OF A MICHELSON INTERFEROMETER USING AN ARDUINO MICROCONTROLLER FORMATION

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Abstract

The Michelson Interferometer is a fundamental optical instrument widely used for demonstrating wave interference, coherence, and precision measurement. This study explores the didactic construction and application of the Michelson Interferometer integrated with an Arduino microcontroller to enhance experimental physics education. The paper details the theoretical background, design, and implementation of an automated Michelson Interferometer system, highlighting its role in measuring optical properties with high precision. By incorporating Arduino-based automation, students gain hands-on experience in modern optical experiments, fostering deeper conceptual understanding and technical proficiency. The results illustrate the system's effectiveness in demonstrating fundamental optical principles and its potential for integration into physics curricula. Furthermore, the study discusses potential advancements in the integration of artificial intelligence for data processing and future developments in optical experimentation [2, 3].

Keywords: Michelson Interferometer, Arduino Microcontroller, Optical Interference, Didactic Experimentation, Physics Education

Introduction

The Michelson Interferometer, developed by Albert A. Michelson, remains a cornerstone of optical physics, utilized in precision measurement, spectroscopy, and fundamental physics research. This study focuses on the didactic potential of the interferometer in an educational setting, particularly its integration with modern microcontroller technology to enhance learning outcomes [4]. The implementation of Arduino-based automation allows for real-time adjustments and data acquisition, making experimental procedures more efficient and accessible to students. This paper discusses the historical significance, theoretical principles, and educational value of the Michelson Interferometer, along with the methodology and experimental outcomes of its automated version. Additionally, the study explores the evolution of interferometric techniques and their role in advancing modern physics, including applications in gravitational wave detection and high-precision metrology [2].

2. Theoretical Background

2.1 Principles of the Michelson Interferometer

The Michelson Interferometer operates on the principle of interference, wherein a single light beam is split into two paths, reflected by mirrors, and recombined to produce an interference pattern [6]. The variations in the optical path difference result in constructive or destructive interference, which can be analyzed to determine various optical parameters, such as wavelength, refractive index, and minute displacement measurements (Figure 1). The versatility of the Michelson Interferometer allows it to be utilized in multiple scientific disciplines, from fundamental physics research to industrial quality control applications [5].

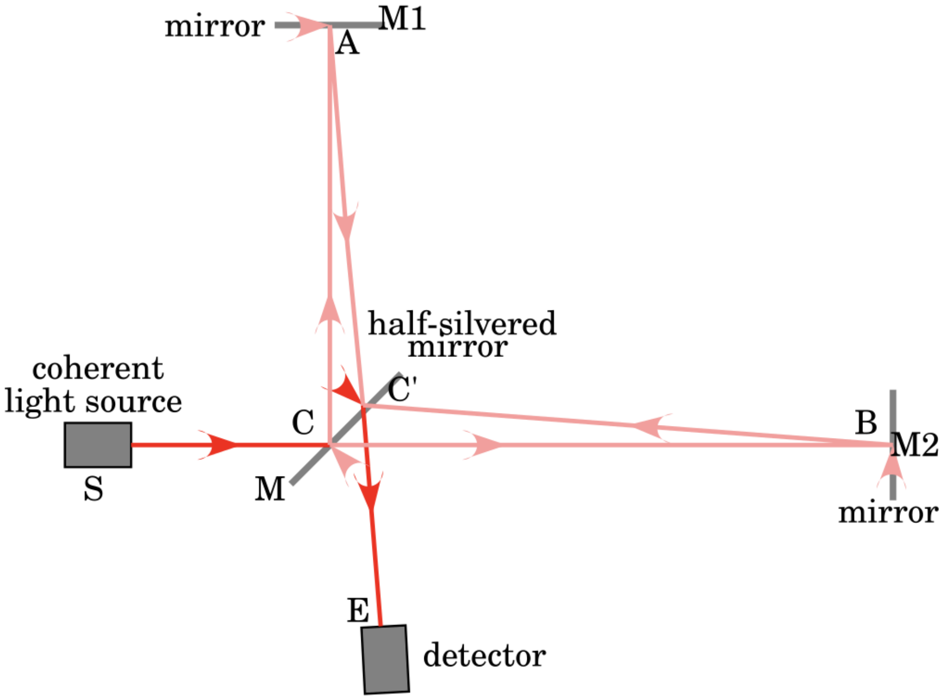

Figure 1. Path of light in Michelson interferometer.

2.2 Fourier Transform Spectrometry

By integrating Fourier transform techniques, the Michelson Interferometer can function as a powerful spectrometer. The recorded interference pattern, or interferogram, can be transformed into spectral data, allowing for precise material characterization and optical analysis [3]. Fourier transform spectrometry has enabled significant advancements in spectroscopy, facilitating highly accurate measurements of complex molecular compositions and enhancing the precision of optical diagnostic tools used in medical and environmental applications [7].

3. Design and Experimental Setup

3.1 Arduino-Based Automation

In this study, an Arduino microcontroller is utilized to automate the measurement process of the Michelson Interferometer. The setup includes:

- A He-Ne laser as a coherent light source
- Beam splitter and mirrors for interference pattern generation
- A photodiode sensor for detecting intensity variations
- An Arduino microcontroller for real-time data acquisition and motorized control of mirror displacement
- Software integration for automated data logging and analysis, enabling students to visualize experimental results dynamically

3.2 Experimental Procedure

1. The interferometer is aligned to produce a stable interference pattern.
2. The Arduino-controlled stepper motor adjusts the mirror position with nanometer precision.
3. The photodiode sensor records intensity variations corresponding to optical path differences.
4. The acquired data is processed and analyzed to calculate parameters such as wavelength shifts and refractive index variations.
5. Additional experiments involve testing the system’s response to external perturbations, evaluating environmental factors affecting interference stability, and assessing calibration techniques for higher accuracy.

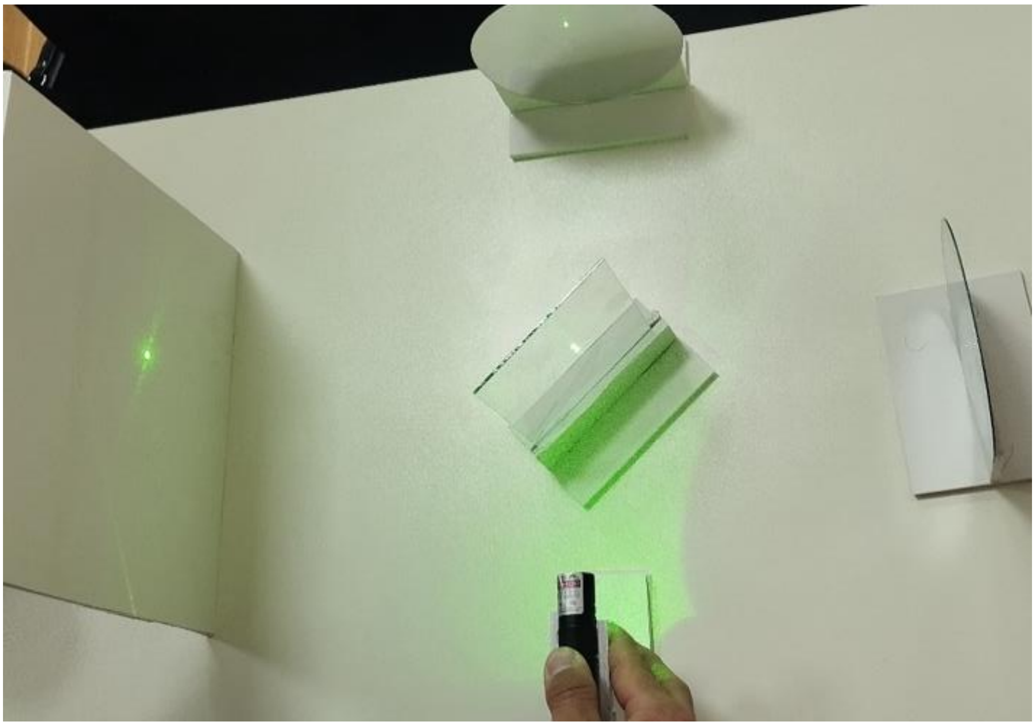

Figure 2. Working process of the project.

3.3 Instruments

- ESP 32CAM – used for monitoring
- Motor driver – controls the two DC motors
- DC motor – drive the wheels
- Jump wire – detect the path
- Power supply – powers the circuit
- Laser
- 3 wheels

Data table:

Distance between two lenses	14cm,12cm
Laser	5V
ESP 32 CAM	5V
Electronic microcontroller	5V
ELN-298	12V
DC motor	5V

Results and Discussion

The automated Michelson Interferometer demonstrated high accuracy in measuring optical path changes, with minimal error margins. The Arduino-based control system facilitated seamless adjustments, improving reproducibility and ease of experimentation. In the Arduino program, there are two necessary functions which are called setup() and loop() [1]. These functions need to be called or declared first; each function usually has a unique name that allows parts of the computer program to run specific commands. The integration of this system in physics education enables students to interactively explore wave optics, enhancing their understanding of interference phenomena and experimental techniques. Moreover, the study highlights the significance of automation in laboratory settings, reducing human error and improving the efficiency of data collection and analysis. Future enhancements could include the incorporation of machine learning algorithms for real-time fringe pattern recognition and adaptive noise filtering to improve measurement accuracy.

Conclusion

This study highlights the effectiveness of integrating an Arduino-controlled Michelson Interferometer in educational settings. By automating experimental procedures, students can focus on conceptual learning while gaining hands-on experience with advanced optical instrumentation. Future work may explore further enhancements, such as implementing machine learning algorithms for real-time fringe pattern analysis and extending the system's applications to advanced spectroscopy. Additionally, the study underscores the importance of interdisciplinary approaches in physics education, demonstrating how combining optical physics with computational techniques can lead to more efficient and insightful experimental methodologies.

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