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# Development Of A Modernized Darkroom For Experiment And Analysis Of Experimental Data

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## ABSTRACT

The absence of functional darkroom facilities in many tertiary institutions significantly limits effective teaching, experimentation, and research in optics. This study reports the design and development of a modernized darkroom for conducting light-based experiments and analyzing experimental data in the Department of Physics, Federal College of Education (Technical), Ekiadolor. The darkroom was designed to provide a controlled illumination environment for optical experiments, particularly those involving image formation and color band analysis using red, green, and blue (RGB) light sources. The facility, measuring 10 × 18 ft, is divided into three functional sections: a preparation (light) section, a light-proof experimental section, and an analysis workspace equipped with computing and ventilation systems. Essential components such as RGB LEDs, optical filters, a pinhole camera, light sensors, image screens, and digital documentation tools were incorporated. The design aligns with contemporary laboratory modernization practices emphasizing controlled illumination and digital data acquisition (Mazzolini & Daniels, 2016; Alves & Viegas, 2018). The developed darkroom enhances experimental accuracy, improves pedagogical outcomes, and serves as a prototype for modern laboratory infrastructure in physics education.

**Keywords:** Modern darkroom, optics experiment, RGB light, pinhole camera, physics laboratory, experimental data analysis

## 1. INTRODUCTION

Light plays a fundamental role in scientific observation, measurement, and technological development. In physics education, experiments involving image formation, diffraction, interference, and spectral analysis require environments in which illumination can be precisely controlled. Experimental reliability and reproducibility in optics depend significantly on minimizing uncontrolled ambient light and employing stable, wavelength-specific sources (Mazzolini & Daniels, 2016).

Traditionally, darkrooms were designed primarily for photographic processing and qualitative observation. However, modern optics experimentation increasingly integrates light-emitting diodes (LEDs), digital sensors, and computer-based image analysis tools. LEDs offer improved spectral selectivity, stability, and energy efficiency compared to conventional incandescent sources (Mazzolini & Daniels, 2016). Furthermore, the integration of digital image processing enhances quantitative data analysis and measurement precision (Gonzalez & Woods, 2018).

Research in physics education has shown that structured laboratory environments that support inquiry-based experimentation significantly improve conceptual understanding and student engagement (Wieman &

Holmes, 2015). Low-cost, modular optical laboratory designs have also been demonstrated to increase accessibility and adaptability in educational institutions (Alves & Viegas, 2018).

In Federal College of Education (Technical), Ekiadolor, the absence of a functional darkroom has constrained effective optics instruction and limited experimental research activities. This study therefore focuses on the development of a modernized darkroom that integrates controlled RGB illumination, experimental measurement tools, and digital analysis facilities.

## 2. Introduction

Darkrooms have historically been essential in photographic science and optical experimentation to eliminate stray light interference. However, conventional darkroom designs are typically limited to complete darkness without provisions for wavelength-selective illumination or integrated data acquisition systems.

Modern optics education benefits from controlled LED light sources, photometric sensors, and digital cameras that enable quantitative measurement of intensity, brightness, and image clarity (Mazzolini & Daniels, 2016). Studies have shown that affordable and adaptable optical laboratory setups can significantly enhance practical learning experiences (Alves & Viegas, 2018).

Beyond technical considerations, laboratory design influences student learning outcomes. Inquiry-based laboratory instruction has been shown to improve scientific reasoning and experimental confidence (Wieman & Holmes, 2015). Additionally, the quality and control of lighting environments affect user interaction and task performance in laboratory settings (Cheng & Chan, 2020; Smith & Jones, 2021).

Given these findings, there is a strong justification for developing a modernized darkroom that combines controlled illumination, experimental flexibility, and digital analysis capability.

The absence of a modernized darkroom facility in the Department of Physics, Federal College of Education (Technical), Ekiadolor, limits the accuracy, repeatability, and pedagogical effectiveness of optical experiments. Poorly structured laboratory environments reduce opportunities for inquiry-based experimentation and limit meaningful data analysis (Wieman & Holmes, 2015). Students are unable to perform experiments requiring controlled illumination, wavelength isolation, and precise light intensity measurements. Therefore, there is a need to design and construct a controlled darkroom setup aligned with modern optics laboratory standards. The objectives include to design and construct a controlled darkroom environment suitable for optics experiments, provide facilities for isolating red, green, and blue color bands using LED technology, integrate measurement and documentation tools for experimental data collection and analysis and to document the design procedure and propose scalable recommendations for laboratory modernization. The study is significant as the darkroom serves as a scalable prototype for laboratory development in colleges of education and universities, particularly in resource-constrained environments.

## 3. METHODOLOGY

### 3.1 Research Design

The study adopted a design-and-development research approach involving planning, construction, equipment integration, and experimental validation.

### 3.2 Darkroom Design and Layout

The darkroom measures 10 × 18 ft and is divided into three functional sections:

#### **Preparation (Light) Section**

This area operates under normal lighting conditions and is used for equipment assembly, calibration, and documentation prior to experimental runs.

#### **Light-Proof Experimental Section**

This compartment is fully shielded from external illumination. Controlled RGB LED sources provide selectable wavelength bands. The choice of LED sources was guided by their spectral stability and suitability for controlled optical experiments (Mazzolini & Daniels, 2016).

#### **Analysis Workspace**

This section houses a computer system for data processing and image analysis. Digital image processing

techniques consistent with established frameworks were employed for experimental analysis (Gonzalez & Woods, 2018).

The overall lighting and layout design were informed by best practices for laboratory lighting systems and user interaction in educational environments (Cheng & Chan, 2020).

### 3.3 MATERIALS AND EQUIPMENT

The following materials were incorporated:

RGB LED light sources

Optical color filters (red, green, blue)

Pinhole camera (constructed using aluminum foil or thin metal sheet)

Image projection screen

Photometer/light sensor

Digital camera

Measuring scale

Stable power supply

Tripod stand

Computer system for data analysis

### 3.4 Experimental Application

The facility supports experiments on pinhole image formation under different color bands. Light intensity, image brightness, and sharpness were measured using photometric sensors and recorded digitally. Image processing techniques were applied to evaluate contrast and clarity which is in line with the work of Gonzalez & Woods, (2018).

The structured environment facilitates inquiry-based experimentation, which has been shown to improve laboratory learning outcomes (Wieman & Holmes, 2015).

## 4 Results and Discussion

### 4.1 Experimental Validation of the Darkroom

Following construction, the darkroom was tested using a pinhole imaging experiment under three controlled illumination conditions: red ( $\lambda \approx 650$  nm), green ( $\lambda \approx 530$  nm), and blue ( $\lambda \approx 470$  nm) LED sources.

Measurements were taken for:

Light intensity (lux) using a photometer

Image brightness (relative pixel intensity)

Image contrast (Michelson contrast ratio)

Image sharpness (edge gradient method via digital processing)

The results confirm that the controlled darkroom environment successfully eliminated ambient light interference and enabled stable, reproducible optical measurements.

### 4.2 Measured light Intensity

Table 1: measured light intensity under different RGB illumination

LIGHT SOURCE	Wavelength , $\lambda$ (nm)	Measured intensity, I (lux)	Standard deviation (lux)
RED LEAD	650	120	$\pm 3.5$
GREEN LEAD	530	150	$\pm 4.2$
BLUE LEAD	470	110	$\pm 3.1$

Table 1 is the measured light intensity under different illumination-red, green and blue light. Green illumination produced the highest measured intensity, consistent with the human eye's peak sensitivity in the green region of the visible spectrum. The low standard deviation values indicate stable power supply and minimal environmental interference. This stability reflects the effectiveness of the light-proof experimental chamber.

**4.3 Image Brightness and Contrast Analysis**

Digital images captured under each color band were processed using grayscale conversion and contrast evaluation techniques consistent with established image processing methods (Gonzalez and Woods, 2018).

Table 2: Image brightness and contrast measurements

LIGHT SOURCE	Average pixel intensity (0 -255)	Michelson contrast ratio
RED LEAD	142	0.42
GREEN LEAD	168	0.48
BLUE LEAD	130	0.39

From table 2, green illumination again produced the highest brightness and contrast values. The increased contrast under green light suggests improved image clarity and edge visibility. These findings are consistent with controlled LED spectral behavior in optics experiments (Mazzolini and Daniels, 2016).

The darkroom environment ensured that brightness variations were due solely to wavelength-dependent effects rather than ambient contamination.

**4.4 Image sharpness**

Table 3: Image sharpness ( Edge Gradient Magnitude)

LIGHT SOURCE	Sharpness index
RED LEAD	0.72
GREEN LEAD	0.81
BLUE LEAD	0.69

From table 3, the highest sharpness index was recorded under green illumination. The consistency across repeated trials indicates reproducibility of experimental conditions within the darkroom.

**5 Overall Discussions**

The experimental results demonstrate that the modernized darkroom provides:

- Stable and controlled illumination conditions
- Reduced external light interference
- Reproducible quantitative optical measurements
- Enhanced image quality under wavelength-specific illumination

The integration of LED-based wavelength selection aligns with modern laboratory standards in optics education (Mazzolini & Daniels, 2016; Alves & Viegas, 2018). Additionally, optimized lighting conditions contribute to improved user interaction and performance in laboratory settings (Cheng & Chan, 2020). Furthermore, the structured experimental environment supports inquiry-based learning and improves data interpretation skills, as emphasized in physics laboratory research (Wieman & Holmes, 2015).

The quantitative consistency across RGB trials confirms the reliability of the darkroom design. The results validate the facility as suitable for experiments in image formation, spectral analysis, photometry, and basic optical imaging research.

**6. CONCLUSION AND RECOMMENDATIONS**

**6.1 Conclusion**

The development of a modernized darkroom addresses critical limitations in optics instruction at Federal College of Education (Technical), Ekiadolor. By integrating controlled RGB illumination, experimental isolation, and digital data analysis facilities, the darkroom enhances both experimental accuracy and pedagogical effectiveness. The design demonstrates that modern laboratory infrastructure can be achieved using locally available materials and informed by contemporary best practices in optics education and laboratory design (Mazzolini & Daniels, 2016; Alves & Viegas, 2018).

## 6.2 Recommendations

1. Tertiary institutions should prioritize the modernization of optics laboratories through controlled darkroom development.
2. Future improvements should incorporate advanced sensors and automated image-processing software.
3. The model should be adapted for secondary schools and technical colleges to strengthen early experimental exposure.

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