A study of the inverse square law using LCD display projectors

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Abstract. Physics experiments on the inverse square law of light was designed and built to help students conduct experiments and learn about the inverse square law of light using LCD display projectors or High Temperature Poly-Silicon (HTPS). LCD displays can be served as two-dimensional gratings. The results show that when a laser light source with the wavelength of 532 nm passes through LCD display projectors, the diffraction patterns are generated on the screen. This pattern can be used to study the inverse square law of light. The correlation between the related variables is 0.997.

1. Introduction

Physics experiments are very important for teaching and learning in physics because they help students prove and verify their knowledge through scientific investigation. Students may discover new knowledge and can also obtain new knowledge and skills through the experimental process. Students need to perform experiments to understand laws of Physics and build up their scientific skills. To do experiments, students need to have apparatus and materials. Some experiment need expensive apparatus. However, we can replace expensive apparatus by unused device or components. For example, we replace expensive diffraction gratings with LCD display projectors. These LCD can be used as two-dimensional (2D) diffraction gratings. These 2D diffraction grating can serves as apparatus for the experiments on the inverse square law of light. The experiment may attract student’s attention. Most physics experiments rely on variable relationships. Some experiments of the relationship between an initial variable and a dependent variable is in direct variable forms, but some experiments can also occur in the form of inverse variation. Especially the inverse variation, which is one of the important fundamental physics experiments. Many experiments have invariant squares also are known as inverse-square law.

This inverse square law can be applied to light and found that when using lasers to pass through rainbow eyeglasses which acted as a two-dimensional diffraction grating, the diffracted light appeared as a square-shaped area of different sizes and the area of the square here corresponded to the square squared distance [1]. It is still repeated experiments to confirm the inverse quadratic law by using two ordinary grating plates to be overlapped perpendicular to each other, that until making the two grating sheets look like two-dimensional grating and when firing a green laser beam at a 532 nm wavelength
passing through to the grating [2]. The experiment showed that light diffraction through the grating appears to be many bright spots on the scene. When measuring the area (multiply width and length) of the area of the bright spot in the middle, the students found that the area varied with the distance between the grating plate and the squared scene. Furthermore, Narayanan and Narayanan have verified the inverse-square law of light by forming the Airy’s disks when 6328 Å light wave from a He-Ne laser is diffracted by a circular hole by moving the screen farther and farther from the hole and made the Airy’s disks larger and larger, measured the areas of the Airy’s disks, illumination of these disks, and the distances of the screen to the hole [3]. Downie also found that the students lost their confidence the they faced with the inverse square law. After having performed experiments, the students understood and enjoyed Physics especially the inverse square law of light [4].

This inverse quadratic law experiment, is not only used to teach students about light, but can also teach radiation and decay. From the experiments, students can learn critical thinking processes by searching for knowledge according to scientific processes [5]. Due to the rapidly technological advancement, Arduino microcontroller board has been used in a simple experiment to measure the brightness of the LED (Light-Emitting Diode) at various distances. The design consisted of a plastic pipe by connecting the signal to the Arduino and the result showed that the graph of brightness in Lux (units) varied inversely with the distance in centimeters [6].

All of the above, this research has proven and confirmed the fundamental physics experiments in the inverse square law of light which is the basic concept of nature. Because students need to improve a critical thinking ability, the experiment requires students to think critically about the relationship between the initial variable and dependent variable. If the students know and understand the relationship of the variables, they will understand phenomena around them. They will be able to formulate and hypothesize by using the initial variable and the dependent variable to find the answer to the phenomena with reasonable reasons such as, light intensity and distance, sound intensity and distance, or the number of particle decay and time, etc.

In this paper, the relationship between the area of light diffraction that appears on the scene (dependent variable) and distance (initial variable) will be studied. This work is different from Physics textbooks which is familiar quantitative relationships. However, the advantage of this research article is the use of LCD projectors (LCD: Liquid Crystal Display) or High Temperature Poly-Silicon: (HTPS) to be used as two-dimensional grating. As shown in figure 1, to study the laser pointer with a wavelength of 532 nm, the experimental design will greatly enhance students’ understanding of the concept of inverse-square law.

![Figure 1. The setup of the inverse square law experiment using the LCD.](image)
2. The purpose
The objective of this paper is to conduct a conceptual experiment on inverse square law of light by using the LCD projector instead of a two-dimensional grating for teaching and learning Physics.

3. Method of research
The following devices and apparatus were prepared for the experiment,
A. laser pointer
B. LCD panel: HTPS, which was a component in the LCD set that was assembled in the projector
C. Tape measure or meter stick
D. Hand grips or tool stands to hold lasers and LCD projectors

Figure 2. Equipment installation to conduct experiments.

Figure 3. LCD panel: HTPS in the projector.

Figure 4. The area of bright spots at 70 cm.
When the equipment as in figure 2 was completed, the distance to fire the laser was specified. Here, a green laser with a wavelength of 532 nm was used. In each laser firing, a beam of light from the diffraction of the laser beam passed through to the LCD panel: HTPS was the device that was assembled in the projector which is a technology (3LCD Technology) as figure 3 with the diffracted light appearing on the scene (bright spots on the scene). The square on the scene consisted of the brightest 9 points counting from the middle points in square centimeters or designated as an area as in figure 4 was assigned. The crystals of the LCD acted as 2-D Diffraction Gratings.

Table 1. Intensity of the light and distance from the laser pointer.

| Distance from point source (m) | Average Intensity of light laser pointer (W/m²) |
|-------------------------------|-----------------------------------------------|
| 1                             | 720                                           |
| 2                             | 549                                           |
| 4                             | 420                                           |
| 6                             | 290                                           |
| 8                             | 220                                           |
| 10                            | 207                                           |
| 12                            | 160                                           |
| 14                            | 140                                           |
| 16                            | 120                                           |
| 18                            | 90                                            |
| 20                            | 60                                            |
| 22                            | 42                                            |
| 24                            | 32                                            |
| 26                            | 22                                            |
| 28                            | 19                                            |
| 30                            | 12                                            |

Figure 5. The Average Intensity of laser pointer varies inversely with the distance.
However, intensity of the laser was measured by a flux (watt) meter in the unit of Watt per square meter (W/m²) at different distances in meter (m) as shown in table 1. Figure 5 is the relationship between the intensity of the laser light used in the experiment which shows inversely proportional to the distance in meters.

The initial (independent) variable of experiment was varied as a distance of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100cm. The data were recorded which consisted of the areas that appeared on the scene which was a square (cm²) and the distance between the scene and LCD in centimeter (cm) as shown in table 2. The graph of the square of the distance (r²) and the area (cm²) are plotted as shown in figure 6.

**Table 2.** The square area of the central bright spot d² and the distance squared r² (where r is the distance between source and screen).

| r² (cm²) | Average area of square d²(cm²) |
|---------|-------------------------------|
| 100     | 1.4                           |
| 400     | 2.8                           |
| 900     | 5.8                           |
| 1600    | 9.7                           |
| 2500    | 14.1                          |
| 3600    | 20.7                          |
| 4900    | 27.3                          |
| 6400    | 35.0                          |
| 8100    | 43.5                          |
| 10000   | 52.2                          |

**Figure 6.** The area of light varies directly with the squared distance.
From figure 6, it can be seen that the relationship between the areas of bright spots that appear on the scene caused by diffraction when the distance between the scene and the LCD in centimeters squared are plotted. It is found that there is a linear relationship with correlations of 0.997.

4. Discussion and summary

From the experimental data shown above, they describe the relation of the square of the distance and the area of diffracted light when passing through LCD that acts as a two-dimensional grating. In the form of direct or linear variation and the relationship of the amount of light intensity in W/m², the intensity unit is inversely proportional to the distance in meter. All of which are relations in the form of initial variables and dependent variables with the application of materials that act as a two-dimensional grating itself. The use of LCD device from projectors to serve as two-dimensional diffraction gratings in our experiments has inspired our high school students and undergraduate students. The students who were involved in the experiments were engaged in learning activities. Instead of being disposed or left to waste, LCD can be made learning apparatus. The experiment could draw the students’ attention and become an effective learning media for the inverse square law of light.

Therefore, if students or people interested in physics may want to understand the inverse square law of light, they may obtain materials or equipment available in everyday life to perform physics experiments. Anything might be an important apparatus for us to learn science, or can be made our large laboratory useful for knowledge acquisition.

5. A suggestion

To carry out the experiments, students and teachers who get involved in performing the experiments should be careful not to have the laser beam shines into the eyes, it can be dangerous. The measurement of light intensity should have the light beam perpendicular to the detector of the watt meter in order to measure the light intensity correctly.

References

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