Analysis on Single Slit Diffraction Experiment Based on MATLAB Simulation

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Abstract. Computer simulation of optical experiments plays an important role not only in scientific and engineering calculations, but also in optical teaching. MATLAB software development tools provide a simple and efficient programming environment for computer dynamic simulation of abstract and complex physical phenomena. In this paper, based on the analysis of the mathematical model of the single slit diffraction phenomenon, a method for computer simulation of the single slit diffraction phenomenon using MATLAB development tools is proposed.

1. Introduction
With the rapid development of computers, optical experiment simulation has attracted more and more attention from scientific researchers and educators [1-6]. The application of computer simulation is mainly manifested in two aspects: the first is in scientific computing, using the results of simulation experiments to guide actual experiments which can reduce and avoid damage to valuable instruments [7]. The second is the application in the teaching of optics. Through the simulation experiment process, the abstract and difficult optical concepts and laws are described intuitively, so that students can grasp the knowledge with interest and use it to carry out exploratory and discovery learning to fully mobilize their enthusiasm.

In this paper, the simulation system is mainly used in single slit diffraction test. The computer simulation process is realized by running the simulation program. When the simulation program is running, the first is to set certain parameter values to the model describing the system characteristics, and let some variables in the model change within the specified range. The results of system operation can be obtained in the process of continuous change via calculation. Therefore, computer simulation has the characteristics of good controllability, non-destructiveness, reproducibility, easy observation and economy, etc. In the optical experimental measurement, it improves the measurement accuracy of the experiment, expands the measurement range and intuitively Influences of parameter changes on experimental results.

2. Theory of MATLAB Simulation in Single Slit Diffraction Experiment
MATLAB has a powerful image display function, which can automatically determine the coordinate drawing according to the input data. MATLAB can draw curves and surfaces in three-dimensional coordinates and set different colors, line types, viewing angles, etc., which is suitable for processing the two-dimensional distribution of complex amplitudes.

In MATLAB, the information of an image is stored in a data matrix (some types of images have a color map matrix). [8] According to the matching relationship between the data matrix and the color of image pixels, images in MATLAB can be divided into three categories: index images, brightness
images, and true color images. In this paper, the image obtained by the simulation program is a brightness image. For brightness images, the element values in the data matrix are generally between 0 and 1 \([0, 1]\) (or between 0 and 255), and the brightness images use linear interpolation based on these data to match the color types in the color map. The data matrix of the brightness image can be either double precision type or integer type. For a double-precision data matrix, the element values are in the interval \([0, 1]\), where 0 represents black and 1 represents white. For values between 0 and 1, it is matched according to the linear interpolation and the color category in the color map.\[9\]

Diffraction is one of the most difficult subjects in optics\[10\]. According to scalar diffraction theory, the diffraction process can be described by Fresnel diffraction integral. However, the Fresnel diffraction integrator under near-field conditions is quite complicated, especially for a diffraction screen with a complex structure, it is almost impossible to obtain its analytical solution.

\[L_i = \sqrt{(y_p - d)^2 + D^2}\]

Figure 1. Geometric relationship of single slit diffraction

Meanwhile, diffraction is a basic property of light waves in space, most practical problems can be handled by approximate method. For single-slit diffraction, the relevant references\[10-13\] give mathematical descriptions of the Fraunhofer diffraction intensity distribution under far-field conditions, and to simulate the formation conditions of Fraunhofer diffraction, the problem must be analyzed from a more general situation. As shown in Figure 1, the slit light source with a width of \(d\) is regarded as composed of \(n\) equally spaced point light sources. Assuming that each point light source has the same light intensity at point \(p\), but the phase is different, according to the Huygens-Fresnel principle \[11\], the normalized light intensity at point \(p\) on the screen can be expressed as:

\[
I_p = \frac{\sum_{i=1}^{n} 2 \cos \left(\frac{2\pi}{\lambda} (L_i - d)\right) + \sum_{i=1}^{n} 2 \sin \left(\frac{2\pi}{\lambda} (L_i - d)\right)}{n^2}
\]

\[(1)\]

Where \(L_i\) is the optical path from the \(i\) point light source to \(p\) point, and \(L_i = \sqrt{(y_p - d)^2 + D^2}\), \(D\) is the distance from the single seam to the receiving screen \(\ldots\). The diffraction pattern is realized by calling MATLAB's image creation function, and the light intensity distribution curve is drawn by the two-dimensional graphical function plot.

3. Results and Discussion

In the experiment, the width of the single slit \(d\) is 0.5mm, and the distance \(D\) from the single slit to the receiving screen can be arbitrarily changed, as shown in Figure 2.
When the width of the single slit is fixed, the distance between the single slit and the receiving screen can be arbitrarily changed to find that the obtained diffraction pattern is different and the spectral curve is also different. By comparing the simulation results in Fig 2, it is found that when the distance $D$ from the single slit to the receiving screen is 500mm, the effect is the best, and the diffraction phenomenon is the most obvious. Then the advantages of MATLAB language can be used in the experiment to explore the factors that affect the experiment from many aspects in order to observe the diffraction fringes and light intensity distribution of the single slit, that is, the distance $D$ from the single slit to the receiving screen of the fixed experiment is 100mm, and change the width $d$ of the single slit arbitrarily (0.01mm ~ 0.4mm), as shown in Figure.
It can be seen from the results in Fig.3 that when the width between the single slit and the screen is 100mm, the diffraction fringes changes with the width of the single slit and the diffraction fringe is more obvious when the width of the single slit is 0.2mm. It shows that when the distance between a single slit and the receiving screen is far, to obtain more obvious diffraction fringes, the slit width requirement is relatively wider. This simulation phenomenon completely coincides with the real optical experiment phenomenon.

4. Summery
By simulating the diffraction process through MATLAB simulation software, the displayed image can be easily processed, and the diffraction phenomenon can be visually displayed. By adjusting the experimental parameters, the diffraction pattern under different experimental conditions can be generated to facilitate the analysis and comparison of the diffraction phenomenon. Improve the efficiency of the experiment.

5. References
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