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Diffraction and Interference of Complex Structure

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Abstract. This experiment mainly studies the interference diffraction phenomenon of two kinds of complex structures. One is to use the hexagonal structure of the watch strap to carry out the interference diffraction experiment of light. By changing the distance between the light source and the hexagon, and the position of the receiving screen to observe the diffraction phenomenon, it is found that the hexagonal interference diffraction phenomenon is obvious, and the distance is an important parameter affecting the interference phenomenon. At the same time, we set up a set of instruments that conform to Kirchhoff diffraction. Using Kirchhoff theory, the relative intensity diffraction formula of diffraction of complex structure-hexagonal-like holes on the screen is derived, and the instrument is used to simulate different incident angles. Different diffraction patterns find out the internal laws between them.

Keywords. Complex structure diffraction; Kirchhoff theory; colony diffraction; wave function

1. Introduction

The diffraction of complex structures is a fascinating topic in the field of nature and science. It covers many disciplines, including physics, materials science, astronomy and engineering [1]. The study of the diffraction phenomenon of complex structures not only deepens our understanding of natural phenomena, but also promotes scientific and technological progress in various fields. The purpose of this thesis is to explore the multiple meanings and applications of the diffraction phenomenon of complex structures to demonstrate its key role in modern science and engineering.

Material science is an important field of application for the complex structure diffraction phenomenon. Researchers use diffraction techniques to characterize and design new materials in this field. By analyzing the diffraction patterns of complex structures in detail, they can reveal key information such as the crystal structure, crystal defects, and grain size of the material [2]. This information is critical for developing high-performance materials, improving the material preparation process, and addressing challenges in materials science. Secondly, it can be applied to nanotechnology and microelectronics. With the development of science and technology, the preparation and characterization of nanostructures become increasingly important [3]. The complex

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structure diffraction phenomenon provides key information for the preparation and performance evaluation of nanodevices. This is critical for the production of highly integrated microelectronic devices, nanosensors, and nanomaterials. By precisely controlling the diffraction of light, optical devices such as lenses, lasers, and waveguides can be designed and optimized. This is of great value for improving the performance of optical systems and expanding the fields of optical applications, such as communication, imaging, and sensing. By studying the diffraction of stellar light through the planetary atmosphere, scientists can obtain information about the planetary atmosphere. In addition, modern astronomical and radio telescopes also rely on the diffraction control of complex structures to obtain clear images of astronomical observations, which promotes our exploration of the universe. At the same time, the diffraction phenomenon of complex structures also plays a key role in information security and encrypted communication. By using the principle of optical diffraction, people can create optical passwords that are difficult to decode, thereby protecting the transmission and storage of sensitive information. Based on the above analysis, this experiment mainly discusses the interference diffraction phenomenon from the complex structure interference and diffraction phenomenon. The complex structure used is the hexagonal structure in the watch belt. Based on Kirchhoff's wave differential equation, the accuracy of experimental calculation is improved theoretically.

2. Hexagonal-like diffraction and interference experiment

2.1 Experimental background

In our life, light is everywhere but also accompanied by interference diffraction phenomenon. The diffraction effect of light was first discovered and described by Francesco Grimaldi in 1665. At the same time, the modern diffraction phenomenon is the basis of the discovery of wave-particle duality. It makes all particles or quantum can be described not only by the term of one particle but also by the term of wave. When Einstein put forward the quantum interpretation of the photoelectric effect, people began to realize that light wave has the dual properties of wave and particle. Is the root cause of the superposition principle and the fundamental theoretical basis in the field of quantum communication. The single-slit and double-slit interference diffraction phenomenon has developed very mature, but the complex structure diffraction has not yet formed a systematic theory. Therefore, based on this, this experimental project studies the complex structure interference and diffraction phenomenon. Understanding the complex structure diffraction phenomenon is conducive to the further development of quantum communication-related fields.

2.2 Experimental principle

The Huygens-Fresnel principle is an analytical method for studying wave propagation problems. It is named after the Dutch physicist Christian Huygens and the French physicist Augustine Fresnel. This principle is applicable to both far-field limit and near-field diffraction. Because the wavelength of light is very short, only a few tenths of microns, usually the object is much larger than it, but when the light is directed to a pinhole, a slit, or a filament, you can see the diffraction of light.

The diffraction of light is usually divided into two categories, one is Fresnel diffraction; one is Fraunhofer diffraction. Fresnel diffraction refers to the case where the distance between the obstacle and the light source and the diffraction pattern is limited. Fraunhofer diffraction refers to the case where the distance between the obstacle and the light source and the diffraction pattern is infinite, that is, the incident light and the diffracted light are both parallel beams, also known as the diffraction of parallel beams [4]. This paper mainly involves Fresnel diffraction, and the experimental principle is shown in Figure 1.

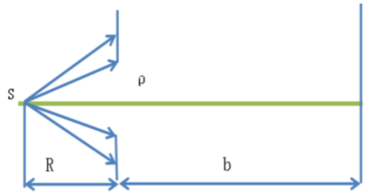

Figure 1. Fresnel diffraction principle diagram

According to the Huygens-Fresnel principle, the spherical secondary wave emitted from any point source Q inside the aperture, and the wave disturbance at the observation screen point P $\psi(\mathrm{x}, \mathrm{y}, \mathrm{z})$ is [5]

$$\psi(\mathrm{x}, \mathrm{y}, \mathrm{z}) = -\frac{\mathrm{i}}{\lambda}\int_{s}\psi(x', y', 0)\frac{e^{ikR}}{R}Kdx' \tag{1}$$

where r = (x, y, z) is the rectangular coordinate of point Q, λ is the wavelength, S is the integral plane (aperture), $\psi(x', y', 0)$ is the wave disturbance located in the wave source Q, R is the displacement vector from point Q to P, R is the numerical value of R, K (x) is the tilt factor, and x is the angle between the normal vector perpendicular to the aperture plane and R.

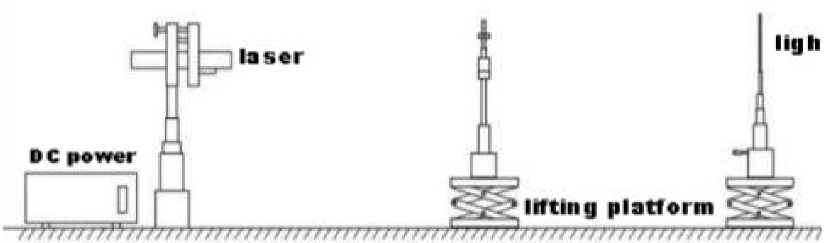

Figure 2. Schematic diagram of laser diffraction system

The structure of the instrument used in this experiment is shown in Figure 2. The experimental instruments are DC power supply, laser (He-Ne laser wavelength is 632.8nm, green light 532nm), light screen, ruler, and lifting platform. In the experiment, by adjusting the height of the lifting platform, the laser is incident on the center of the hexagon and the diffraction interference image is presented on the light screen. This experiment records different diffraction interference images generated by changing the distance between the hexagon and the light source [6,7]. The complex structure used in this experiment is shown in Figure 3.

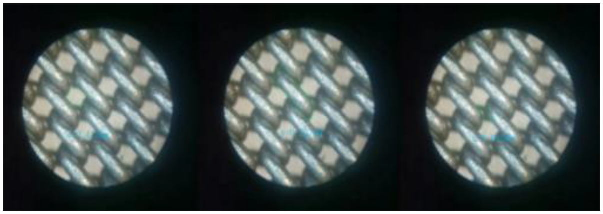

Figure 3. Diffraction principle diagram of hexagonal-like structure

2.3 Experimental data

The experimental data mainly involves the complex structure area, and the method used is to measure the average value many times. The diffraction pattern involved in this experiment is shown in figure 4. It can be seen from the figure that obvious diffraction phenomena can be observed in this experiment. The whole presents two sides of the shape, the stripes are bright and dark, and there is a lack of level phenomenon. With the increase of the distance between the light source and the complex structure, the different distances in the diffraction have a great influence on the diffraction. The bright and dark fringes correspond to the vertical edges and the distance between the fringes becomes smaller and smaller with the increase of the distance, and the central structure becomes more and more obvious. The difference in diffraction phenomenon is related to the distance from the complex structure to the light source and the distance from the light source to the observation screen.

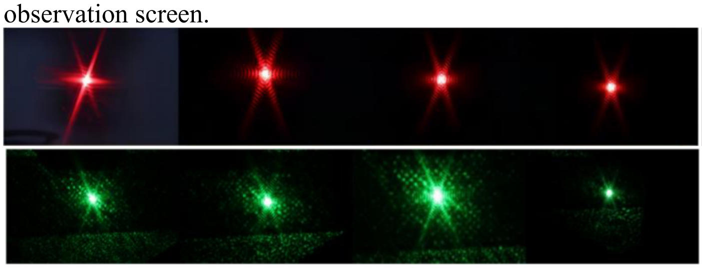

Figure 4. Semiconductor laser diffraction image

2.4 Results and discussion

It is observed that the laser spot is a hexagon composed of four arrays through a complex structure. Kirchhoff has found a more perfect mathematical expression for the Huygens-Fresnel principle from the differential wave equation [8]. The theoretical formula is:

$$U_P(X,Y) = C\int_A\int e^{ikr}\mathrm{dA} \tag{2}$$

Where Up (X, Y) is the value of the electromagnetic wave function of any point on the screen, r is the distance from a small facet of the hole to any point, k is the wave vector value of light, and C is a negative constant [9,10]. The relative intensity of the light can be expressed as:

$$\mathrm{f_p}(X,Y) = \int_A\int_{\mathrm{e}} \frac{-\mathrm{ik}\ (xX+yY)}{R} dA \tag{3}$$

$$\frac{I_p(X,Y)}{I_0} = \frac{|f_p(X,Y)|^2}{A^2} \tag{4}$$

3. Conclusions and prospects

In this study, the basic operation principle of complex structure is preliminarily completed. Based on the simulation of various situations, the observed phenomena are analyzed and summarized, but there is still room for further optimization. In this study, only considering a light source is far from meeting the needs. How to establish a comprehensive sample library is worthy of our further research. The clarity of the camera and the accuracy of the measurement are the primary bottlenecks. If more accurate observation of the diffraction phenomenon of complex structures is needed, more advanced imaging methods are an important aspect of future improvement. Most of the systems currently designed need human intervention, and the error is large. To further optimize the system, a more automated experimental system can be designed for operation.

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