Experiment Teaching Based on Physics Innovation--Development and Application of Virtual Simulation of Holographic Technology

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Abstract

Virtual reality technology and modern education are the current trends and development goals of immersive personalized education. Combining the development and application of holographic technology and virtual simulation technology will help to innovate and experience the immersive personalized education model. This paper is an experimental practical application of virtual simulation immersion teaching. From the three aspects of experimental plan design, teaching method innovation, and evaluation system innovation, experimental teaching such as holography, rainbow holography, holographic data storage, holographic grating production, and compound grating optical differential processing are used. Innovative design, Taber effect can not only help students fully understand relevant knowledge points, but also focus on cultivating students to master the structure and use of commonly used optical components, and experience different teaching effects.

Key words: *Holographic technology; Mach Zender; Interference optical path*

1 INTRODUCTION

The existing education system is static and extensive, and cannot achieve personalized education. Immersive technology is not bound by the laws of physics, educators can create experiences that engage students in new ways, coupled with the use of technologies such as gesture tracking and deep learning, students can see and touch holograms anywhere. Immersive technology products include augmented reality glasses and other devices that utilize technologies such as VR and AR. There is no doubt that immersive technology is the next big computing platform, completely redefining the relationship between people and information. The following discusses the practical application of virtual technology in physical teaching, so that students can experience immersive education.

2 TEACHING INNOVATION DESIGN

2.1 *Experimental design ideas:*

Through repeated practice of virtual and real, master the use of virtual experiment software, conduct holographic display and reproduction experiments based on Mach-Zendel interference optical path, and then complete the experimental report through online experimental operation and data analysis. Then carry out experiments related to the enrichment and expansion of offline projects. The teaching and scientific research team introduced the virtual simulation experiment of the research results with strong operability, good inspiration and good application value into the undergraduate experimental teaching course. The experiment has been applied to the undergraduate experimental teaching of electronics majors, which further improves the students' practical ability of hands-on experiment and stimulates the students' interest in scientific research.

Students can learn in advance through the virtual simulation experiment platform and become familiar

B. Fox et al. (Eds.): IC-ICAIE 2022, AHCS 9, pp. 675-682, 2023.
https://doi.org/10.2991/978-94-6463-040-4_103

with various operating procedures, thereby relieving the pressure of offline experiments and improving the motivation of students to actively study.

2.2 *Innovation in teaching methods:*

In order to improve the practical experimental ability of undergraduates and to better realize the connection between teaching and scientific research, we have set up optical experiments in the undergraduate teaching of electronics, computer science, aerospace, mechatronics, solar photovoltaic materials and other majors. It is a research and exploratory experiment designed by the scientific research back to the teaching. The experiment needs to use the exploratory experimental method, the basic principle verification method and the self-made experimental instrument method commonly used in scientific research. There will be many errors, such as the adjustment of the laser, the measurement of the holographic grating, the presentation effect of the interference optical path, etc. Especially in the experiment, there are many steps that need to be adjusted continuously, with high uniformity, such as laser gripper, reflection. The adjustment of the mirror bracket and the beam splitting prism bracket requires precise adjustment and is time-consuming. In addition, in order to verify the success of the experiment, it is necessary to use helium-neon lasers, spatial filters, collimating mirrors, mirrors and other equipment to build holographic shooting and reproduction optical paths, and to measure and analyze the results, and the interference phenomenon is not easy to show. Therefore, in order to improve the efficiency and intuitiveness of the experiment, it is necessary to use the teaching method combining virtual and real.

2.3 *Innovation of evaluation system:*

According to the students' offline and online experimental process teaching big data and comprehensive scores of experimental preview, operation familiarity, data processing, experimental report, etc., students are guided to study deeply and realize the personalized experimental teaching process. The characteristics are as follows:

(a) Autonomy orientation. It has a page-oriented function, and learners can follow certain requirements, adopt appropriate learning strategies, conduct online learning, and conduct learning evaluations independently, obtain feedback, and achieve self-improvement.

(b) Openness. It can provide learners with rich learning resources through the Internet, and can also obtain real-time or asynchronous learning support through the network platform.

(c) Interactivity. It supports a variety of interactive functions, through which learners can actively participate in learning.

(d) Reusability. The course content can be updated and revised in time to make it more timely and adaptable.

It also has its own special properties:

(a) Focus on performance. The course is strong in practice, which improves students' scientific thinking and practical operation ability.

(b) Practicality. It is oriented to solve the problems in the operation of the students.

2.4 *Extension and expansion of traditional teaching:*

(a) Online virtual simulation experiment and offline experimental teaching combine virtual and real, with reality as the main and virtual as the supplement, to develop a new experimental teaching mode for traditional experimental teaching to improve experimental efficiency and students' sense of participation.

(b) Virtual simulation experiments can make up for the lack of experimental equipment, reduce the risk of using hazardous chemicals, improve safety, and reduce the purchase of large and expensive equipment and reduce costs.

(c) The standardized technology and standardized interface developed by the virtual simulation experiment is a virtual experiment platform with good extensibility and scalability, which can not only meet the experimental needs of teachers and students, but also serve scientific research institutes and enterprises in related disciplines.

3 OBJECTIVES OF EXPERIMENTAL TEACHING

1. Understand the basic principles of holography.

2. Learn the construction of holographic optical path diagrams, and take holograms.

3. By observing the reproduced images of holograms, understand and summarize the characteristics of holograms and their essential differences from ordinary photography.

4. Master the recording and reproduction principles of image plane holograms.

5. Master the principle and method of making a one-step rainbow hologram, and make a one-step rainbow hologram, and observe its reproduced false color image under white light.

6. Understand the basic principle of Fourier transform hologram.

7. Master the principle of holographic storage and the method of extracting information.

8. Understand the principle of holographic grating.

9. Learn how to build a Mach-Zehnder interferometer and make holographic gratings.

10. Master the method of grating constant measurement and verification. [1]

4 EXPERIMENTAL PRINCIPLE

(1) Experimental principle

a) The principle of holography

Holography is a photographic technology that displays three-dimensional images of objects, which is fundamentally different from ordinary photography. It has real parallax and large depth of field, so it has a real three-dimensional sense.

Ordinary photography is to condense the light emitted or reflected from the surface of the object through a lens and record the image with a photosensitive film. Since the response time of the existing optical recording medium is much longer than the period of the vibration of the light wave, it can only record the light intensity - the square of the light wave amplitude, but cannot directly record the phase of the light wave, so it cannot obtain a three-dimensional image. Record.

Holography not only records the amplitude of the object's light wave, but also records its phase. This method records all the information of the object's light wave front, so it is called "holography", also known as wavefront recording. Using the principle of diffraction of light, the light waves of objects can be restored and reproduced. [2]

Holography not only records the amplitude of the light wave of the object, but also records the phase, and the recording medium is only sensitive to the intensity of the light (the square of the amplitude), so the phase must also be converted into amplitude information and recorded, the interference effect of light ——The superposition of two columns of coherent light waves produces bright and dark interference fringes (interference patterns), which are not only related to the amplitude of these coherent lights, but also related to the phase. In order to produce the interference effect to record the phase, another beam called reference light can be used. It is done by the interference of coherent light and the light wave of the object. Most of the recording and reproducing optical paths commonly used now are the "off-axis" hologram optical paths proposed by Leith, that is, the object beam and the reference beam reach the recording medium from significantly different directions. A typical optical path for such a hologram recording is shown in Figure 1:

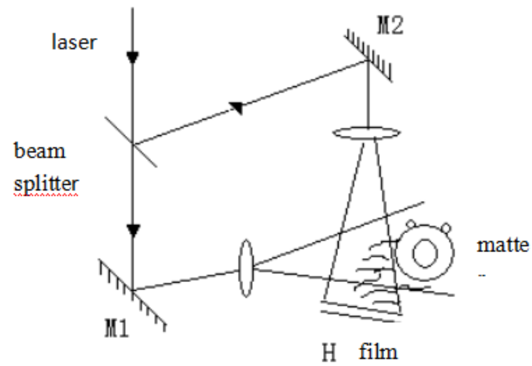

Figure 1 Typical optical path for hologram recording

Light emitted from laser is divided into two beams by beam splitter wedge, one of reflected beams reaches mirror, and then is expanded by beam expander to illuminate holographic film (this is the reference beam), and the other beam is transmitted to the mirror, and beam expander expands beam to object, and then object is diffusely reflected to holographic film to form object beam. Object beam and the reference beam are superimposed on holographic film, resulting in interference and various interference patterns such as fringes, rings, and spots with different light and shade, which are recorded by photosensitive emulsion on film, and become a hologram after being developed and fixed. (hologram). The shape of interference fringes on hologram reflects the phase relationship between object light and reference light, and light-dark contrast reflects intensity of object light. [3]

It can be seen from the figure that the recording process of holography is different from that of ordinary photography. It does not need a lens, so it is also called lensless imaging, and the recording process is essentially a process of light wave interference.

Mathematically, it can be expressed as follows:

Assuming that X0Y is the holographic dry plate plane, the Z axis is perpendicular to the plane, and the object light and the reference light are respectively expressed on this plane as:

$$O(x,y)=O_0(x,y)e^{i\varphi_0(x,y)} \tag{1}$$

$$R(x,y)=R_0(x,y)e^{i\varphi_R(x,y)} \tag{2}$$

The combined amplitude and light intensity of the two trains of light waves interfered on the plane of the film are:

$$A=O+R$$

$$I=(O+R)(O^*+R^*)=OO^*+RR^*+OR^*+O^*R$$

$$=O_0{}^2+R_0{}^2+O_0R_0e^{i(\varphi_0-\varphi_R)}+O_0R_0e^{-i(\varphi_0-\varphi_R)}$$

$$= O_0^{\ 2} + R_0^{\ 2} + 2O_0R_0\cos(\varphi_0 - \varphi_R) \qquad (3)$$

Equation (3) is the basic formula for holographic recording.

When the photosensitive hologram is developed and fixed, and then irradiated with laser light, there is an amplitude transmittance T, that is, the ratio of the complex amplitude of the transmitted light to the complex amplitude of the incident light. During linear recording, the amplitude transmittance T and the intensity of exposure light proportional, that is:

$$T = \beta I \qquad (4)$$

Reproducing light waves $C = C_0(x, y)e^{i\varphi_C(x,y)}$ When irradiated, light waves are transmitted through:

$$A = CT = C\beta\left(O_0^{\ 2} + R_0^{\ 2}\right) + C\beta OR^* + C\beta OR$$

, where is β a constant, for simplicity, C_0 it is often omitted in, so that

$$A = \left(O_0^{\ 2} + R_0^{\ 2}\right)C_0e^{i\varphi_0} + C_0R_0O_0e^{i(\varphi_C+\varphi_0-\varphi_R)} + C_0R_0O_0e^{i(\varphi_C-\varphi_0+\varphi_R)} \qquad (5)$$

This is the reproduction of the hologram, also known as the formula for wavefront reproduction. The first term in the formula indicates that the reproduced light wave will continue to be directly transmitted after passing through, the second term represents the original image, and the third term represents the conjugate image.

b) Features of holography

Since holography is the recording and reproduction of wavefronts, it has different characteristics from ordinary photography:

(1) True stereoscopicity. The hologram records the three-dimensional image of the object, which can be better understood by observing the holographic reconstruction.

(2) The hologram is diffusive, even a fragment of a broken transmission hologram can still reproduce the complete image of the photographed object through laser illumination.

(3) The hologram can reproduce the virtual image and the real image at the same time, especially when the reference light is illuminated by parallel light, it is very easy to observe. To reproduce, just flip the holographic negative once.

(4) Holographic photography can perform multiple recordings, and multiple holograms can be recorded onthe same holographic negative only by appropriately changing the incident angle of the reference light relative to the holographic negative.

c) Classification of holograms

1. Planar holograms and volume holograms

2. Absorption and phase holography

This experiment is a diffuse reflection holography.

d) Knowledge points: a total of six

1. Recording and reproduction of holograms

2. Diffraction grating

3. Holographic Storage

4. Fourier Transform Hologram

There are many classification methods of holography, mainly including the following:

1. Transmission holography and diffusion holography

2. Fresnel holography and Fraunhofer holography

3. Rainbow Hologram

4. Volume Holography

(2) Simulation design of core elements (truthfully describe the experimental scene of the objective structure, function and motion law embodied by the simulation model of the system or object, within 500 words)

a) Mach-Zehnder interference structure: It is necessary to simulate the interference process and the effect of interference fringes according to the law of physical optical interference.

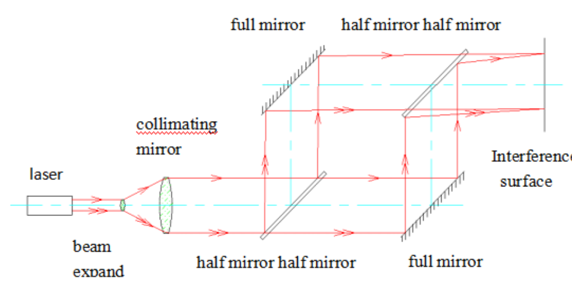

Figure. 2 The principle diagram of Mach-Zehnder interference

b) Simulation of interference holographic imaging effect: It is necessary to simulate the holographic imaging effect under different interference imaging structures according to the principle of holographic imaging:

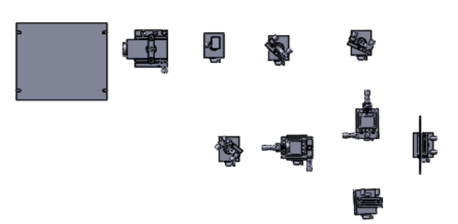

Figure 3 Holographic imaging simulation experiment equipment diagram

5 EXPERIMENTAL TEACHING PROCESS AND EXPERIMENTAL METHODS

The experimental teaching process includes "pre-class preview", which requires students to have good practical training literacy and relevant basic practical skills in advance, basic three-dimensional cognition ability and proficient computer operation ability, and learn relevant theoretical knowledge according to the experimental instruction book, so that students perform the virtual operation of the experiment on the computer, become familiar with the operation process of the virtual experiment, and are familiar with the adjustment and use of the Mach-Zendel interference light path; master the optical principle of the holographic recording process; It can enable students to understand the Fourier transform hologram generation principle, holographic storage principle and volume holography, etc., and master the optical path of rainbow holography experiment and its construction and adjustment methods: using exploratory and interactive teaching methods, students are required to operate according to the prompts in the virtual simulation platform, and learn to use the Mach-Zehnder interference optical path to establish holographic records and make holographic gratings And test methods, familiar with the formation principle of holography. After the students master the experimental principle, they apply for the assessment. After the assessment, the system will automatically record the operation results. Those who fail the training need to re-practice the training operation; pass the experimental evaluation and submit the test report. The final grade is assessed by the teacher.

The experimental method is to reproduce the holographic recording and holographic reproduction process through virtual simulation software. Complete the adjustment of the Mach-Zehnder interference optical path and interference law in the virtual environment (first adjust the level of the helium-neon laser, then expand and collimate the laser beam, form the interference conditions after splitting and combining the beams, realize the interference effect, adjust the mirror The pitch and yaw directions can change the thickness and direction of the interference fringes). At this time, if one beam of light is used as the reference beam, another beam of light is irradiated on the object to form the object beam, and the interference reference beam forms the hologram. Using dry plate recording, holograms can be recorded. After the recording is complete, the light of the object can be blocked. At this time, the object can still be reproduced by reverse observation; holographic grating, storage, and volume holography also use the principle and optical path; rainbow holography introduces a special imaging relationship, and the influence of laser wavelength on the holographic reproduction process can be ignored at this time, even if white light is used as the reference light , it can also reproduce holographic information, data measurement (by recording holograms, reproducing holograms, making holographic gratings and other information), recording and processing data, recording the corresponding image information and data to the operation interface, and processing the data to obtain the corresponding Image information and data, and record the data into the corresponding forms and files. The experimental process focuses on the adjustment process of laser and holographic optical paths, the observation process of holographic recording and information reproduction phenomena, and the 3D observation of the optical path adjustment process. [4].

6 STEP REQUIREMENTS (NO LESS THAN 10 STUDENT INTERACTIVE OPERATION STEPS. THE OPERATION STEPS SHOULD REFLECT THE SUBSTANTIVE EXPERIMENTAL INTERACTION, AND STEPS SUCH AS SYSTEM LOADING ARE NOT INCLUDED)

6.1 *Interactive operation steps for students, a total of 10 steps*

Table 1: Interaction steps

step number	Step target requirements	When the steps are reasonable	Goal Achievement Score Model	step full marks	Grade Type
1	He-Ne laser level adjustment	10’	5’	5’	Operational results experimental report
2	Laser collimation beam expansion adjustment	10’	5’	5’	

3	Mach-Zehnder interference optical path adjustment	10’	5’	5’	Preliminary grades Teacher Evaluation Report
4	Hologram shooting	10’	5’	5’	
5	Reproduction of holographic information	20’	10’	10’	
6	Holographic grating production	15’	5’	5’	
7	Rainbow Holographic Shots	10’	10’	10’	
8	Reproduction of rainbow holographic information	15’	20’	20’	
9	Optical storage recording and reproduction	10’	10’	10’	
10	body holography	15’	25’	25’	

6.2 *Detailed description of interactive steps*

The difficulty of the experiment lies in the adjustment part of the laser and the data acquisition and operation process of the holographic recording and reproduction phenomenon, especially in the operation of adjusting the laser and expanding the beam collimation using the 3D operating system, which allows students to have a stronger operating space And the process of understanding the instrument, the observation process of holographic image shooting and holographic information reproduction can give students a strong intuitive understanding, and the phenomenon is obvious.

Description of the experimental method:

After the user enters the system, click "Start Experiment". Use the ASDW four keys to control the scene movement, Z and X keys to control the scene zoom, hold down the right mouse button and drag left and right to realize the screen rotation.

7 CONCLUSIONS BASED ON HOLOGRAPHIC TECHNOLOGY DEVELOPMENT AND APPLICATION:

a. Laser adjustment: turn on the laser, adjust the level of the laser, make the laser beam pass through the iris at near and far distances, and fix the height of the iris;

b. Holographic optical path construction and holographic dry plate shooting processing: install the beam splitter wedge, rotate the mirror ring of the beam splitter wedge, so that the transmitted light and reflected light will not be deflected in the up and down direction, and fix the mirror ring. That is, the light after the beam passes through the beam splitting wedge can still pass through the iris diaphragm, which will be used as the optical path adjustment height scale in the following experimental steps. Adjust the dichroic wedge knob so that the reflected light from the dichroic wedge passes through the iris diaphragm both near and far. Insert a mirror in the transmitted light path, and adjust the mirror knob so that the beam passes through the iris diaphragm both near and far. Place the target at the rear of the object light reflector, place a white screen at the back of the reference light, and fix the position of the target and the white screen. on the screen. Measure the optical path of the object light with a tape measure, and adjust the position of the reference light reflector so that the optical paths of the two optical paths may be nearly equal. Insert the spatial filter behind the mirror respectively, and use the iris diaphragm as a height ruler to adjust the height of the spatial filter (without pinhole), so that the laser beam passes through the center of the expanded beam spot after the microscope objective and the center of the iris diaphragm. Coincidently, the spatial filter height is locked at this time. Add a pinhole, rotate the thread, push the objective lens close to the pinhole, when the transmitted light has no diffraction ring and the light intensity is the strongest, the spatial filter adjustment is completed. Fine-tune the spatial filters of the object light and the reference light so that the light spots of the two beams are as coincident as possible. Adjust the circular adjustable attenuator at the rear of the reference light reflector so that the light intensity of the object light and the reference light on the white screen is approximately 1:3. Adjust the angle between the object light and the diffuse reflection of the target object to the holographic dry plate, generally between 35 degrees and 55 degrees. Insert the electronic shutter between the laser and the beam splitter wedge to open the electronic shutter. Fixed shutter height. Select the exposure time. When the laser output power is about 50mw, it is generally set to 30-50 seconds, and the shutter is closed. Turn on the safety light, turn off other light sources (also turn off the laser). Remove the white screen, and clamp the holographic dry board cut in advance in the dark room on the dry board clamp. Let stand for 2-3 minutes, turn on the laser, and press the electronic shutter switch (the film surface of the holographic dry board should face the object to be photographed, please do not walk or speak during the photographing process). Development time depends on D-76 developer concentration. When the holographic dry plate is rinsed in the developer, pay attention to observe that it can be taken out when part of the dry plate becomes black. The time is about 10-20 seconds. Rinse the dry board in clean water for 30 seconds, and then rinse it with F-5 fixer for about 20 seconds. Finally, rinse the dry board under running water and dry it with a hair dryer. (Note: When dissolving the developer powder and fixer powder, try to operate according to the package instructions, the water temperature is too low, the developer powder and fixer powder will not be dissolved, and the concentration will be reduced). Put the rinsed dry plate back on the dry plate clamp, remove the object to be photographed, block the light of the object, and illuminate the holographic dry plate with the original reference light, and you can see the virtual image of the location of the object.

Figure 4 Imaging effect

8 CONCLUSION

Students will be assessed after practical training, and the assessment results will be automatically recorded and judged by the software. Students need to write and submit test reports and experimental experiences after class. The experimental report includes experimental purpose, experimental principle, experimental instrument, experimental content and steps, experimental precautions, experimental result analysis, etc. The purpose of the experiment requires students to understand the meaning and purpose of the experiment; the principle of the experiment requires students to master the basic theoretical knowledge of the experiment and draw the corresponding schematic diagram; the experimental instrument requires students to list the instruments required for this experiment and understand the operation method of the instrument; The experimental content and steps require students to briefly describe the operation steps and matters needing attention during the operation; the analysis of experimental results requires students to reasonably analyze the problems in the experimental process and the final results. The experimental experience includes students' cognition of the experiment, what they have learned from this experiment, and suggestions and opinions on this experiment. [5]

The diversity of data will also be highlighted through the comparison of experimental process and design. That is, it analyzes the proficiency of the students' steps, and also reflects the students' pre-class preview. On the other hand, through the holographic shooting process, the students can better understand the holographic process, cultivate their rigorous scientific attitude, and better confirm the authenticity of the experimental data and the importance of the operation process. When the data exceeds too much, An error message is displayed asking students to double-check the cause of the problem.

ACKNOWLEDGEMENT

Thesis affiliated project: Jiangxi Provincial Department of Education Science and Technology Project; NO. GJJ212122.

Research on the Simulation Application of University Physics Experiment Based on VR Technology.

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