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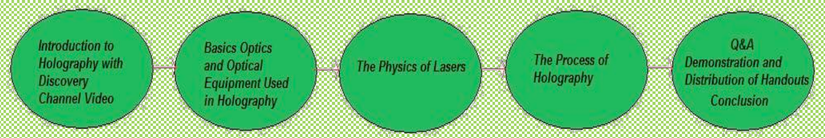
INTRODUCTION

This guide is designed to show someone with a basic undergraduate background in physics how to perform a presentation on the topic of holography and how to demonstrate the making of a hologram. Although holography can be a very complex area of study, the material has been explained mostly qualitatively, so as to match the target audience's background in mathematics and physics. The target audience high school students in grades 9- 11 and so limited to no previous knowledge on optics, lasers or holograms is assumed. The presentation and demonstrations will teach the students about basic optics such as reflection, refraction, and interference. The students will learn the basic physics of lasers, with a focus on the apparatus set up of a laser and the necessity of a coherent light source for the creation of interference patterns. The last part of the presentation covers the two most popular types of holographic production apparatuses which are reflection and transmission holograms respectively. Some historical background and fun facts are also included throughout the presentation. The module ends with a live demonstration on how to make a hologram to give the students some exposure to the care that must be taken in experiments and to give them a taste of what higher level physics laboratories can include. The following flow chart summarizes the basics of how the presentation will flow.



LIST OF EQUIPMENT

- Laptop
- Digital Projector
- Clickers and Clicker Equipment (Number of clickers depends on number of students)
- Hologram Kit
-
- Green Safelight
- Handouts
- Speakers

PREPARATION FOR PRESENTATION

First and foremost, you should find out the location you'll be presenting at and when the presentation will take place. You should find out who your target age group is and the name of the teacher of the class you're presenting to would be nice to have so you can address them politely and have a contact person in case you have any questions. You should find out how much time you'll be given so you can scale the length of the presentation accordingly. The Demonstration is intended for grades 9-11, so no prior knowledge is assumed, thus you do not have to change the presentation depending on the age group, however, if you're to present to younger grades, you should inform the teacher that your presentation might not be age group appropriate. The maturity level of the students will vary depending on the year and you should keep this in mind when you're presenting.

It is crucial you make a few holograms on your own before you attempt to demonstrate the process in front of a class. The sooner you can do this the better, but you definitely should have a few trial holograms made before you demonstrate it- the process can be very tricky and it takes practice to perfect! You don't want to disappoint students by making a fuzzy hologram or one that's not clear at all. You'll need a dark room to do the demonstration in so make sure you tell the teacher that at one point you'll need to turn almost all the lights off in the classroom aside from the green safe light.

Make sure you make a few extras of your hand out sheets in case the number of students given by the teacher was inaccurate. For this reason, you should also make sure to have a couple of extra clickers also. Ensure all clickers work at least a few days before you present. Make a checklist of the equipment needed and have all of this ready and packed a couple of nights before. Make sure you store all your equipment in a safe place to ensure it does not get stolen.

PRESENTATION GUIDELINE

(Follows the slide show)

Introduction

Holography is an interference method of recording the light waves diffracted by an object illuminated with a coherent light source such as a laser. The word hologram comes from the Greek word "*holos*" meaning whole. This is appropriate because unlike a photograph which only captures the irradiance distribution of an object, the hologram captures of more true to life image. The hologram is a recording of the actual object wave, and not the image of the actual object. In order to describe the process in which a hologram is produced the following ideas will be looked over.

Basic Optics

A good place to start when explaining basic optics is to ask the students what they think light is and what they think waves are, etc. This will open up the students to start thinking about the new ideas being presented and will give you a feel of their level of understanding. The first thing you should explain to the students is that in basic optics, light waves are approximated as or represented by directed straight lines. You should explain that light can be manipulated to do many different things. It can *reflect* off of mirrors. It can change direction or bend, as seen when one puts a rod into a glass of water and the rod appears to have been bent. Of course we know that the rod itself does not bend, but the path of the light being reflected off of it is *refracted*, to change direction, giving the illusion of the rod being bent. Refer to the picture in the slideshow of this. Then explain the following figure shown below.

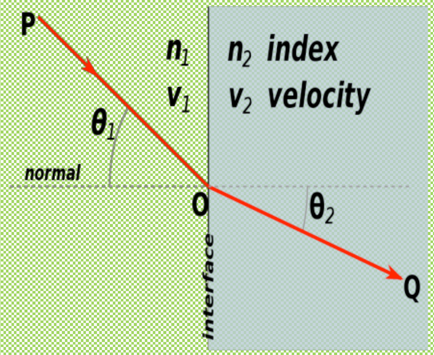


Figure 1-1

Explain how the incident beam is P and how the interface would be analogous to the interface between the glass of water and air. Note how the light beam is bent inwards, or changes path. Stress that this process of changing direction of light is what is referred to as refraction. You might also want to mention that is can be seen the other way, as the incoming beam coming from the water and how the light is bent outwards when it travels from a denser medium to a less dense medium (water is denser than air).

Thus, the density of a material will determine whether a light beam will bend more inward compared to the original, or get bent more outwards.

Diffraction of light waves should be a new concept to most high school students so it is probably best to explain diffraction by analogy with water waves. Every student has seen ripples in a pond and the pattern it creates. You can use this and the visual aids in the slideshow to explain the interference. This would be a good time to play the video showing the water waves interference pattern and the several images which show different pattern. An example image from the slideshow is pictured below.

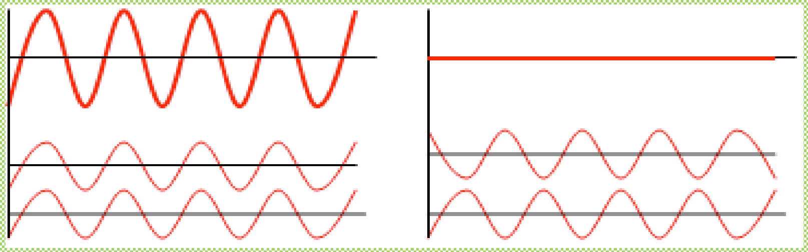


Figure 1-2

For example, for this image you would stress how waves which overlap perfectly or are congruent "add up" where as waves which are complete opposite in shape "fully" subtract. Perfect adding up is constructive interference, where as perfect subtraction is destructive interference.

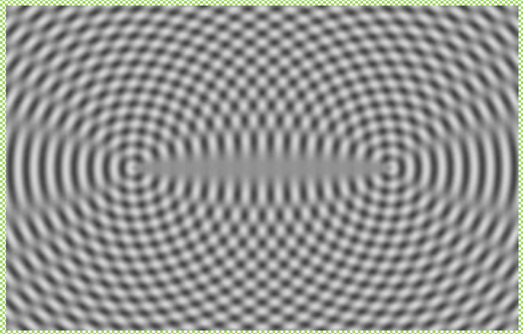


Figure 1-3

When this image comes up, you should stress that the dark areas are the destructive interference areas and the white is where fully constructive interference occurs. The grey areas would be where the waves don't perfectly add up or subtract, resulting in a medium intensity areas.

Lasers

What does Laser stand for?

L – Light

A – Amplification by

S – Stimulated

E – Emission of

R – Radiation

The laser is a device that was designed to turn electrical energy into light energy. It is designed based on three man components, the energy source, the gain medium and two or more mirrors making an optical resonator. When the two mirrors are set up properly multiple reflections through the medium are possible. In order for the wave to grow in intensity inside of the cavity it must first of all be travelling parallel to the axis of the two mirrors.

There is then a second condition, in which the wave must return through the medium in phase, otherwise there will be destructive interference and the wave will be “reabsorbed” .The waves in phase with the source experience stimulated emission as they pass through the source, as constructive interference amplifies the wave. This is known as lasing and produces a beam of coherent light which is necessary in holography.

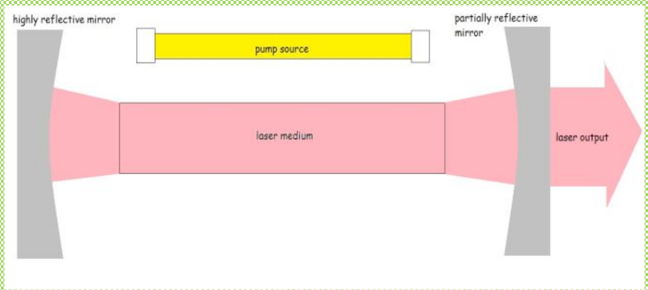


Figure 1-7

Coherent Light

This is a major factor for holography. If the light source is incoherent, different frequencies, the hologram will not work. A hologram is a recording of interference between the reference and the object wave. There the laser is used for this reason since it produces a coherent beam of light.

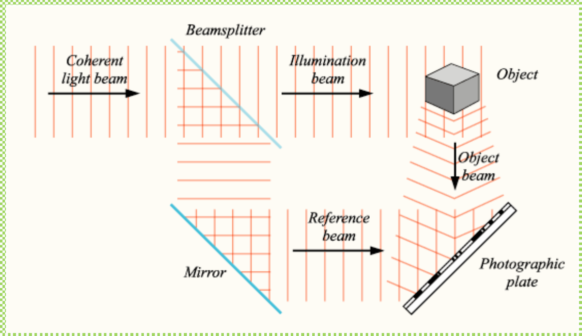


Figure 1-8

Types of Holograms

Now that the basic optics have been explained qualitatively, you can move on to explaining how some of the components in a holographic set up work. The easiest component of the set-up to start with is the mirror, as light is simply reflected back off of the object (almost perfectly with no absorption). Then explain how a lens works. Refer to the slide on the different types of lenses and show how concave mirrors cause incident light to diverge, or be spread out, where as convex lenses cause light beams to converge to a focused point

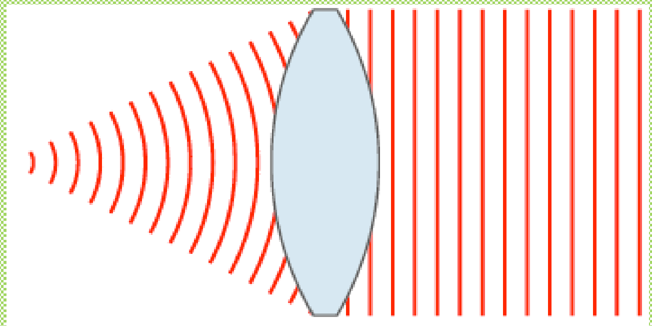
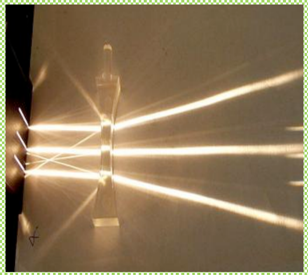


Figure 1-9



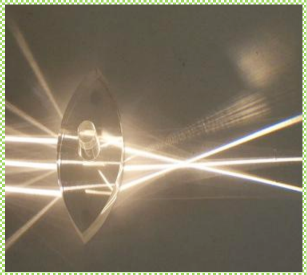


Figure 1-10 **Figure 1-11**

The beam splitter involves both reflection and refraction. Refer to the diagram in the slideshow to explain how some light is reflected off the surface of the beam splitter and how some is transmitted, and how this process repeats over and over again until you have one full beam reflected and one full beam transmitted in different directions. Thus, the beam splitter *splits* the beam.

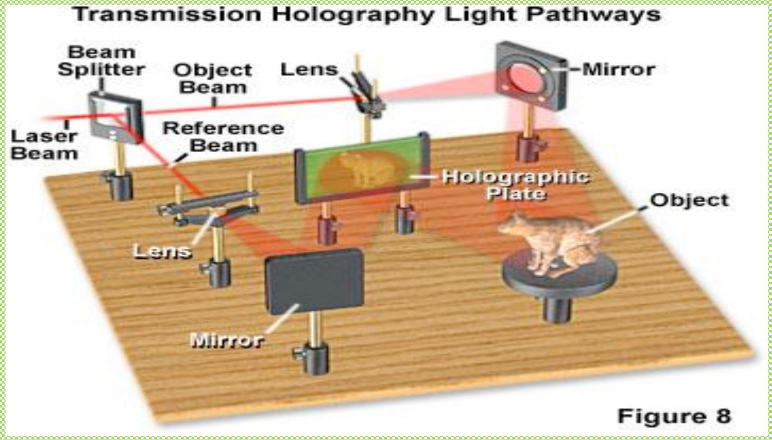


Figure 1-7

Now that the majority of the science involved in the holographic process has been explained, you can begin to explain the different types of hologram production set ups using scientific terminology. The two most common types of holographic set-ups are reflection holograms and transmission holograms. This segment is designed to combine all new topics learned throughout the presentation to explain how a basic hologram is produced. Of course, most students won't be able to recall in detail everything that has been covered previously so as you go through this segment, feel free to refer to previous slides which explain each component of the set up individually to refresh their memory. Make sure to take time to ask students if they have any questions after each step of the holographic process is explained to ensure no one gets lost throughout the explanation. When the transmission hologram slide is put up, begin at the laser, and briefly explain again that a laser is an approximately monochromatic and coherent light source compared to white light from common incandescent light bulbs and how this is necessary for a basic hologram to be able to record diffraction patterns. Next re-explain how the basic (dielectric) beam splitter works to transmit and reflect the laser light in different directions, giving rise to an object beam and reflection beam. State that the object beam will be used to illuminate the object that the hologram will copy, where as the reference beam is used to create a diffraction pattern in the recording process. Now would be a good time to refer to the previous slide about how different shapes of lenses can cause light to converge or diverge an incident light beam and how the lenses in a hologram set up diverge the laser beams so that the object beam is able to illuminate the object and reflect off of it. Now that the reference beam and object beam are ready for use, explain how, by reflection, some of the spread out laser light incident on the object will reflect back to the holographic plate. The mirror will direct the reference beam so that it is also aimed at the holographic plate. This is where interference comes into play. Interference is a new concept to most high school students so it would be a good idea to refer to previous slides in the slideshow which show typical interference patterns between light waves and water waves so that the students can visualize the process in their minds. Since photochemistry isn't the main focus of the module, you don't have to go into detail about how the interference pattern is recorded on the holographic plate. It is sufficient to say ______. Then say how after the hologram is recorded, we of course place the holographic plate in a developer, etc.. This will all be shown in the demonstration later on and is not the main focus of the module, so you can simply refer to an analogy about how we develop regular 2D photographs using film and developing solution.

By this time, each component has been re-explained along with the apparatus for the transmission hologram so explaining the reflection hologram will be easy. Simply go through the process from laser to holographic plate again, this time without referring to previous slides, and explain the differences between the two types of set ups. Use the diagram on the next slide labelled "Reflection Hologram Set-Up". A reflection hologram does not require a beam splitter, but it still uses a reference beam and an object beam. The laser beam is diverged using a lens and is first passed through the photographic plate as a reference beam where it interacts with the emulsion. The light then reflects off of the object placed behind the holographic plate to act as an object beam. The reflected light (object beam) and incident light (reference beam) interacts with the emulsion to record a diffraction pattern on the holographic plate. Thus a beam splitter isn't necessary.

A main difference between reflection holograms and transmission holograms

Transmission holograms use both the reference and object-illuminating beams on the same side of the film to produce an effect that is similar to the one from reflection holograms (Figure 8). One set of laser waves is utilized to illuminate the object being imaged, which reflects the waves and scatters them in a manner similar to ordinary illumination. In addition, a polarized reference laser beam is applied in a direction that is parallel to the hologram film plane. Scattered (reflected) light waves reach the film emulsion simultaneously with the reference waves, where they interfere to create the image from fringe patterns. Transmission holograms have a number of applications, but one of the most interesting is the **heads-up display** utilized by pilots. In a traditional aircraft cockpit the pilot must constantly shift his attention between the windows and the control panel. With the holographic display, a three-dimensional transmission hologram of the aircraft controls is reflected onto a disk positioned close to the pilot's eye, so the pilot can view both the controls and the horizon simultaneously.

DEMONSTRATION GUIDELINE

(How to do the demonstration)

Refer to the demonstration guideline that comes with the Hologram kit.

REFERENCES

Works Cited

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