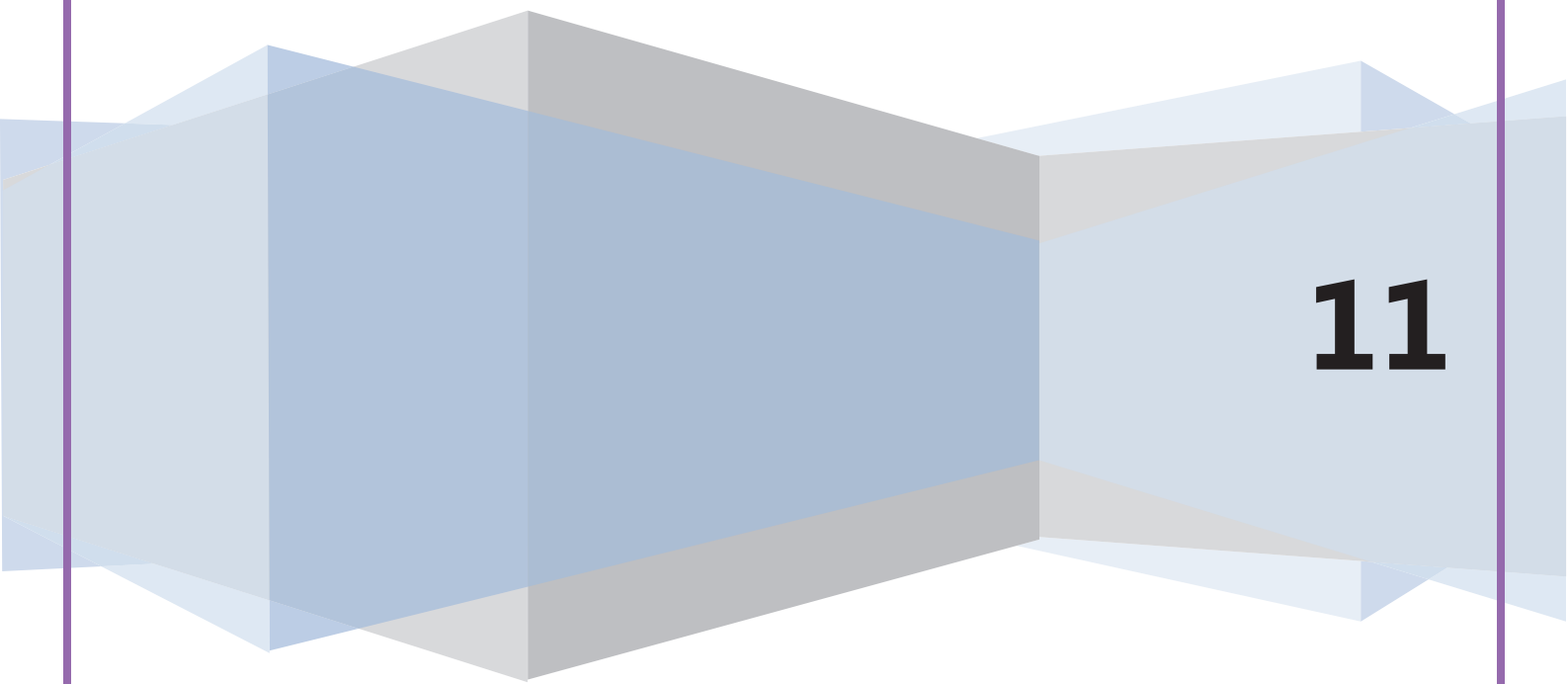
A Whole Lot of Holograms

Star of the Sea College Gardenvale

By Georgia Riordan, Tess Della Piana, Isabelle Lam, Claudia Ohlert, OliviaPerazza, and Jess Tang-Lacy



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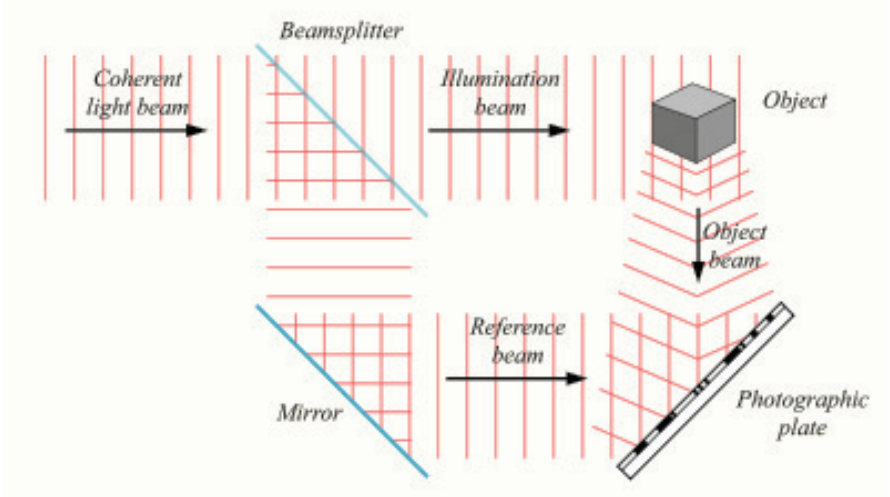
PROJECT OVERVIEW

From Monday 20th to Friday 24th June, Star of the Sea college students Georgia Riordan, Olivia Perazza, Isabelle Lam, Tess Della-Piana, Jess Tang- Lacy and Claudia Ohlert were lucky enough to participate in the Growing Tall Poppies program. We came to Melbourne University to join forces with the CXS Ultra Cold Plasma Lab to investigate holograms. Learning about the work of the Ultra Cold Plasma Lab has showed us its helpful uses in life, and getting our hands dirty and playing with holograms has not only been really fun but also allowed us to better understand diffraction. Diffraction is when a beam of light hits and object and bounces off it.

WHAT IS A HOLOGRAM?

A hologram is a three-dimensional image formed by the interference of light beams from a laser or other coherent light source. The diagram below shows the path that a laser creating a hologram would take. It starts with the coherent light beam hitting a beam splitter and separating into two equal light sources; the object beam and the reference beam. The object beam is reflected by a mirror to hit the object that the hologram will resemble, whereas the reference beam goes straight to the photographic plate. The two intersect and create an interference pattern that is burnt into the photographic film. This creates a hologram and the only way that the hologram can be viewed is by re-shining a light of the same wavelength as the reference beam at the same angle on the photographic plate.

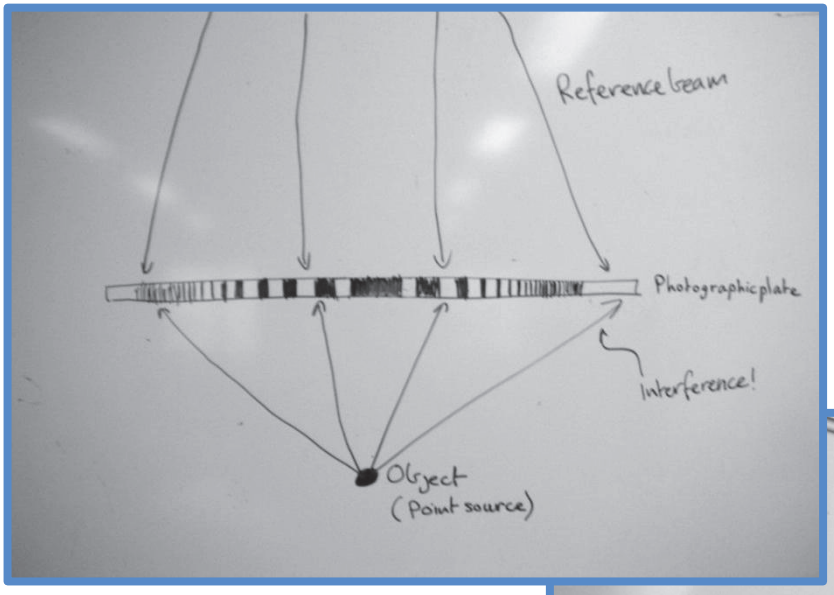


HOLOGRAMS AND PHOTOGRAPHS

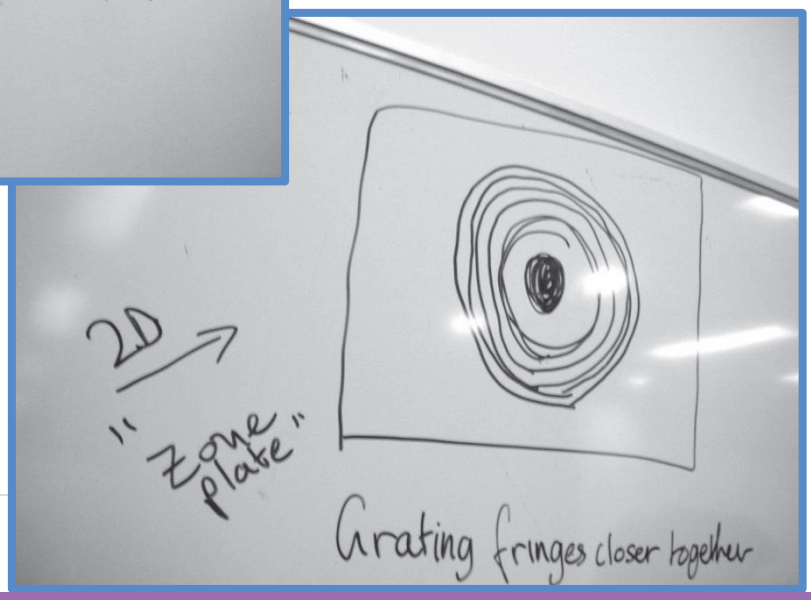
Photographs can only show a 2D image because the light wave that is recorded onto the film only contains information about the wave's amplitude. Holograms however, record information about the wave's amplitude and phase which gives the perception of depth, creating a 3D image.

WHY DO HOLOGRAMS APPEAR 3D?

Holograms appear 3D because when the laser burns the interference pattern into the photographic plate it makes the grating fringes space out in the centre and closer together towards the edge. When you re-shine the reference beam onto the hologram, the beams of light "continue" to where the object would be, therefore, the object looks like it is behind the film. The entire object is made up of many point sources and each is made up of a zone point. The grating fringes that are closer together have a bigger reflection angle, whereas the ones that are far apart have a smaller reflection angle.



Point Source Diagram

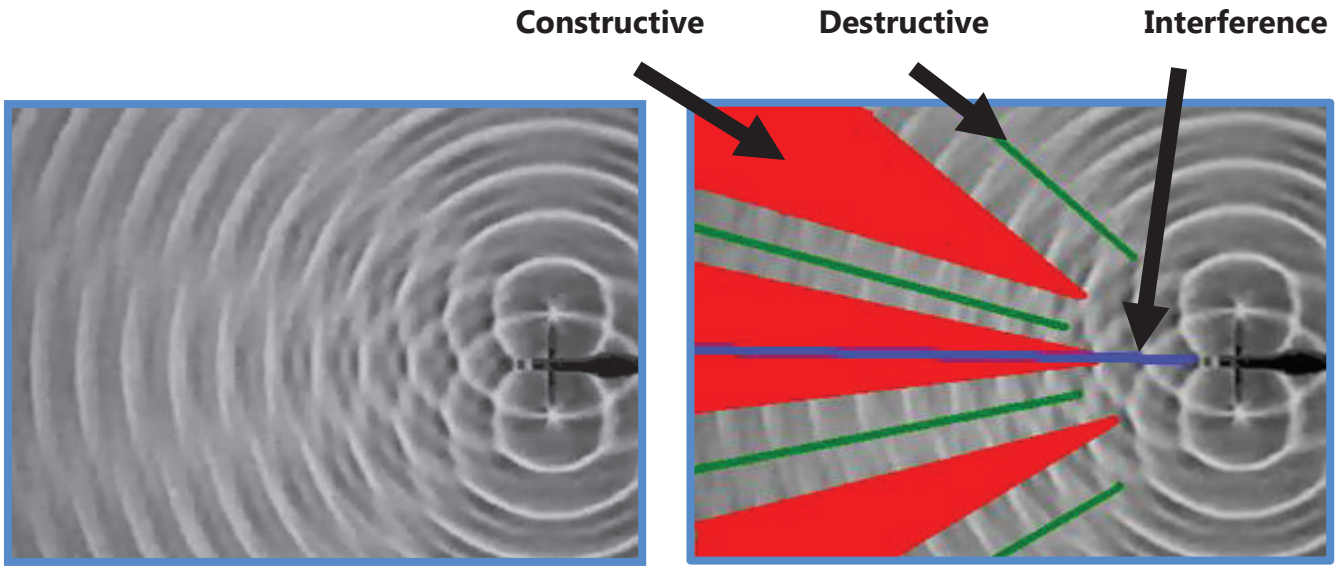


Zone Plate Diagram

CONSTRUCTIVE AND DESTRUCTIVE LINES

Diffraction takes place when a beam of light (either coherent or incoherent) hits an object and bounces off. When either the crests or troughs of a wave overlap with each other, the amplitude of the wave doubles. The phase of these waves will then equal zero because the two intersecting waves are travelling at the same time. This is called constructive interference.

When the crests or troughs of a wave coincide, given that the wave has the same amplitude, they will cancel each other out. The phase of these waves will equal π because the two waves at these points are going at opposite times and cancel each other out to create a straight line. This is called destructive interference.



Making a Hologram

AIM

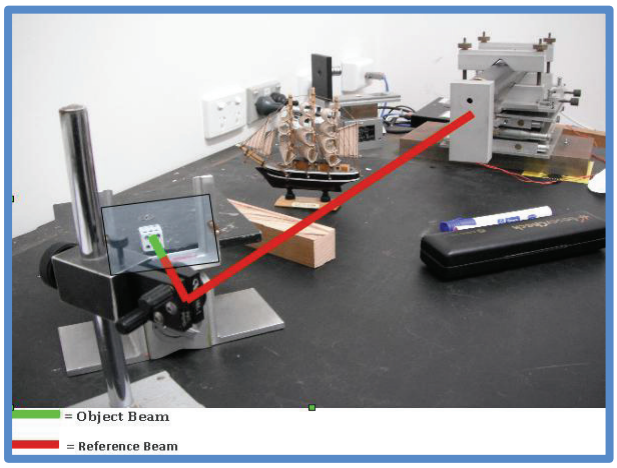
To investigate the process of creating holograms and how different variables such as light intensity and exposure time can affect the quality of the hologram.

HYPOTHESIS

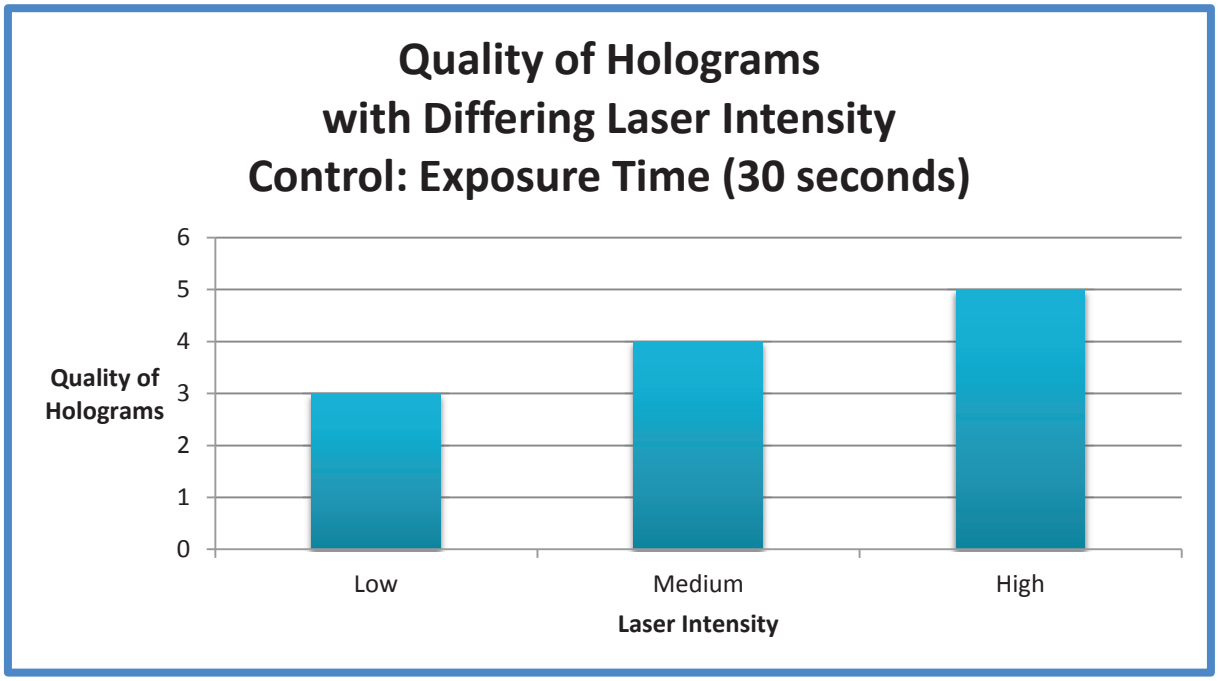
If the laser is at a high intensity and the exposure time is thirty seconds the hologram produced will be of good quality. If the material and colour are contrasting to the laser, both reflecting and absorbing the beam, the overall hologram produced will be more successful.

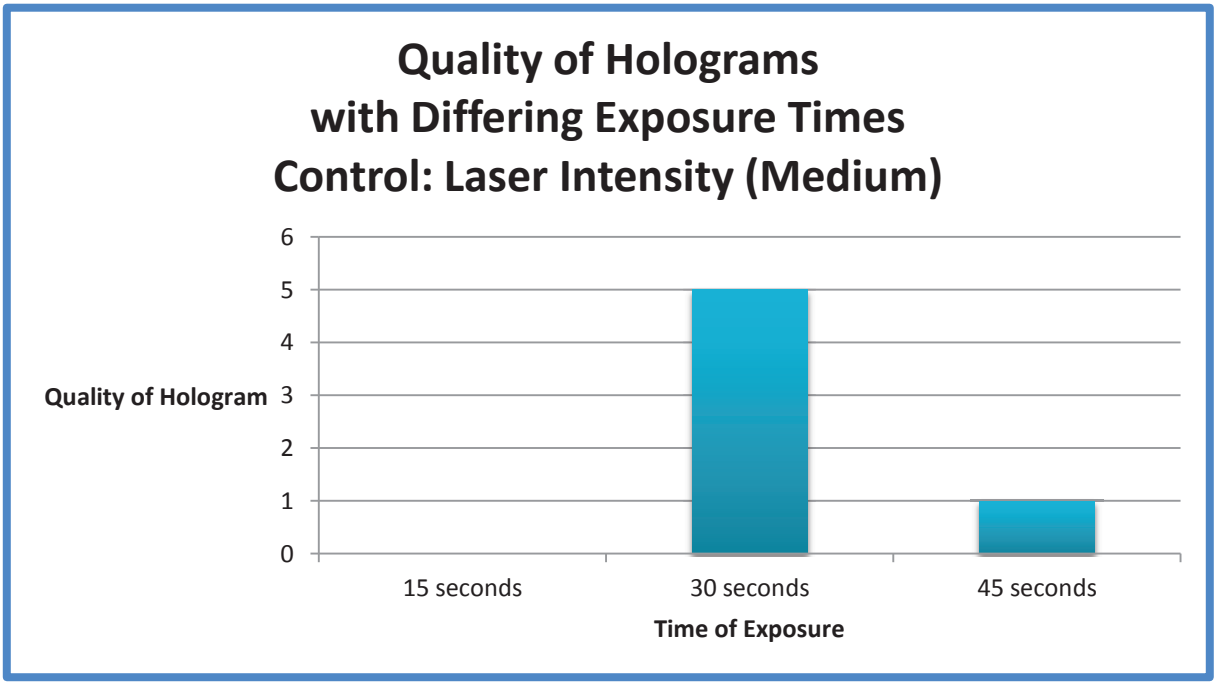
METHOD

1. Place the object you want to create a hologram of onto the stand
2. Make any adjustments to the proximity of the mirror and the stand to alter the intensity if needed. This is done by leaving the mirror in its place and moving the stand closer of further away
3. Make sure that the mirror is reflecting the beam onto the desired object, making any adjustments to the angle of the mirror in order to alter the position of the beam
4. Turn off the lights and slide in the holographic film onto the stand
5. Turn on the laser and wait for the desired exposure time before turning the laser off (once the laser has been turned off the green light may be turned on)
6. Remove the holographic film and using tongs dip into different concentrations of isopropylene
7. Once dipped into each solution, lift the hologram with tongs and leave on a drying rack by a heater to dry
8. Cover with contact to protect and lengthen the life of your hologram
9. The hologram can now be viewed by being placed under a light source

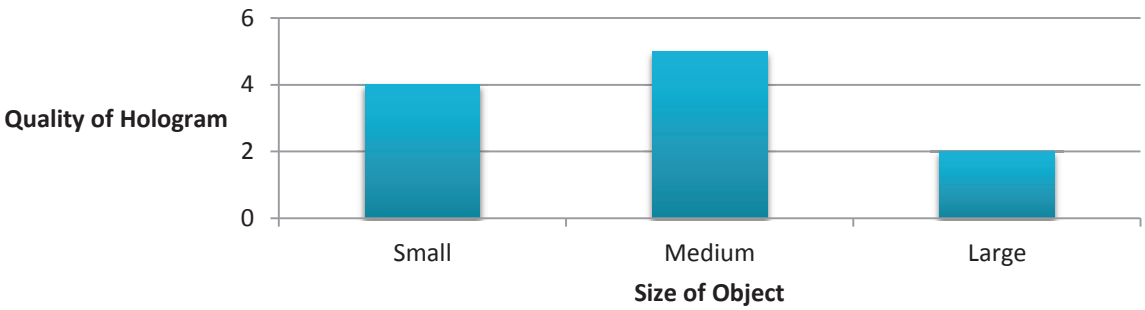


RESULTS:

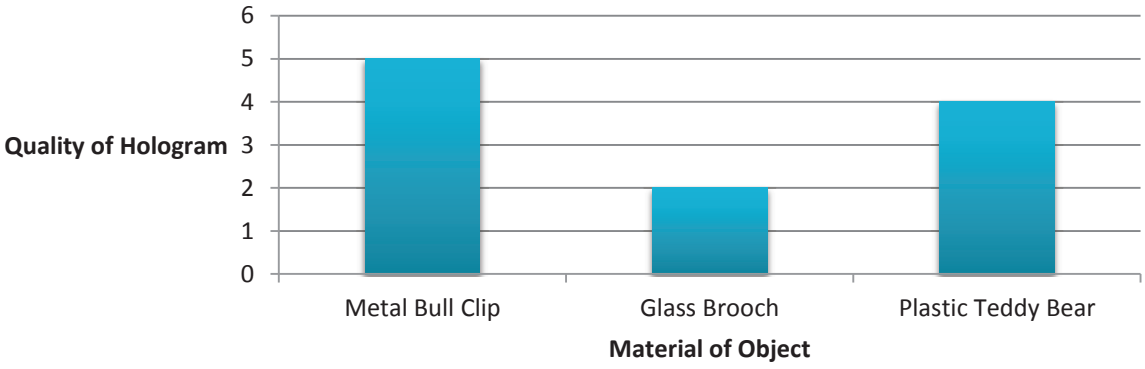

Quality of Holograms
with Differing Laser Intensity
Control: Exposure Time (30 seconds)
Quality of Holograms
6
5
4
3
2
1
0
Low
Medium
High
Laser Intensity


Quality of Holograms
with Differing Exposure Times
Control: Laser Intensity (Medium)
Quality of Hologram
6
5
4
3
2
1
0
15 seconds
30 seconds
45 seconds
Time of Exposure

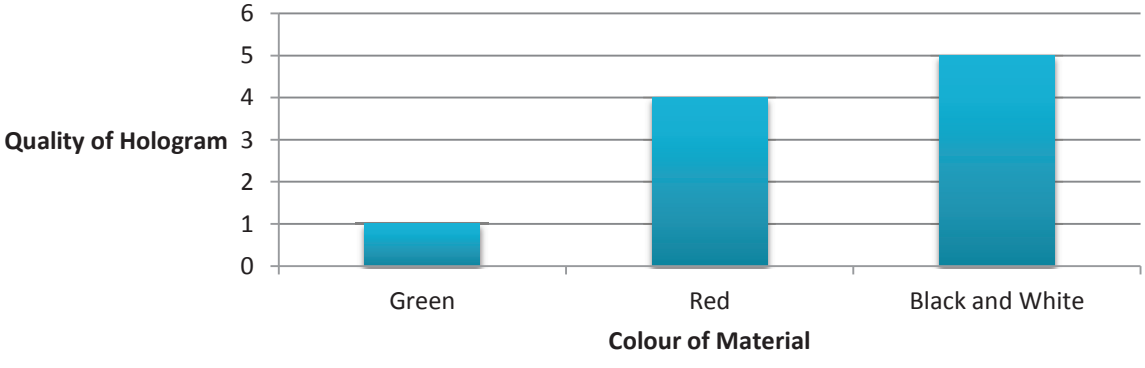
Quality of Holograms with Differing Size Controls: Exposure Time (30 seconds), Laser Intensity (High)



Quality of Holograms with Differing Materials Controls: Exposure Time (30 seconds), Laser Intensity (High)



Quality of Holograms with Differing Colour Controls: Exposure Time (30 seconds), Laser Intensity (High)



DISCUSSION

It is evident from the results that the exposure and intensity were the variables that greatly influenced the clarity of the holograms. The laser intensity that provided the best hologram was high with the exposure time of 30 seconds. The high intensity laser and exposure time of thirty seconds were therefore used as controlled variables in the other tests as they were proven to produce the best quality hologram. The material, size and colour of the object also gave varying results.

The material results proved the metal bulldog clip and plastic teddy bear to be more effective than the glass brooch and the ideal size of the object was proven to be medium (around 3cm tall and wide). It is apparent that contrasting colours such as the black and white die show up in the hologram clearer than dark colours which merely absorb the laser light. The colour red reflects the red laser light and the object does show up significantly in the hologram however using one colour proves not as effective as using contrasting colours. The colour green is not effective for creating a hologram as the green colour absorbs and does not reflect the red laser light.

CONCLUSION

Changing the variables ultimately changed the clarity of the final hologram produced. Using and adjusting different objects, exposure times and intensities, we were able to determine which variables produced holograms with more definition and clarity. In conclusion, our hypothesis was proven accurate and most holograms turned out successful.

A Hologram of a Dice

CXS

CXS stands for Coherent X-Ray Science. It includes a group of leading Australian researches who are physicists and biologists working together to study X-ray physics and explore X-ray free electron lasers. One of the branches that CXS deals with is biotechnology and the non-crystallographic structural determination of biological samples.

WHY IS THE CXS RESEARCH IMPORTANT?

This research is important because using electron or X-Ray crystallography is one of the few ways to view tiny sub-cellular structures to expand our knowledge of things that are just too small to see under a microscope. Being able to look at these objects allows scientists to examine their structures and the way that they work. This vital information can lead to the development of cures for diseases and solving world problems such as malnutrition.

THE CONNECTION OF CXS TO REAL WORLD PROBLEMS

The work done by CXS is closely connected to solving issues in the real world. The imaging that can be done by X-Rays is powerful enough to be used to observe cells and thus understand them and compare them to other things. Using the images of cells that we obtain under the X-Rays, assists in the creation of drugs that can cure diseases as the creators can see how the drug helps, or harms, specific cells.

INTERDISCIPLINARY APPROACHES

The work done by CXS contributes to not only Physics but Chemistry, Biology and Maths. Chemists and Biologists can use the imaging which CXS makes possible to view cells and elements which is too small to see with a microscope. This enables many different sciences to be able to utilise the benefits of CXS.

WHY SHOULD HIGH SCHOOL STUDENTS CARE ABOUT SCIENCE?

"Science is the greatest of all adventure stories."
Brian Greene

Science is a way to understand ourselves and our surroundings. New discoveries can drive a young student to want to learn the details of life and the world around us. Science is an important practical tool that can be applied to the rest of one's life.

IMPORTANCE OF STRUCTURE

DETERMINATION OF MEMBRANE PROTEINS:

Membrane proteins live in the membrane of the cells of living organisms. They control and regulate what enters and exits the cell. This makes them very important in drug design and investigating how viruses and drug molecules interact with cells. However, these proteins are difficult to work with as they are unable to be crystallised. The work of Ultra-Cold Plasma Labs explores alternative techniques that can be utilised to be able to view these membrane proteins and better understand their structure and shape.

THE ULTRA COLD PLASMA LAB AND DETERMINING THE STRUCTURE OF MEMBRANE PROTEINS

The Ultra Cold Plasma lab extracts the electrons from atoms and fires them at elements and molecules that cannot be crystallised. This is done by diffraction. To do this you have to fire a laser that has a wavelength of 780.24nm at Rubidium (Rb) atoms in an attempt to slow the atoms down to 30nm/s. The aim of slowing the atoms down is to make them cold. You then fire six different red lasers at the atoms, which ionises them. These electrons do not fly away, but they form plasma around the Rubidium Cations. These electrons can then be fired at the bio-molecules. The electrons emit light enabling us to see the uncrystallised molecule very clearly. You cannot use normal visible light to see the molecules because the wavelengths are too big, unlike with electrons whose wavelengths are smaller than the molecules that they are trying to see. The electrons then diffract off the molecule and create a diffraction grating which can be measured to give you the structure of any given molecule.

THE AUSTRALIAN SYNCHROTRON

The trip to the Australian Synchrotron was definitely a beneficial experience for us all. It allowed us to understand the corporation of physics, especially diffraction, in determining the structure of proteins. We gained an understanding of the processes in a synchrotron, such as how electrons are accelerated to the speed of light and then transferred into a storage ring. These fast moving electrons are bent using bending magnets, which results in the emitting of electromagnetic light. The electromagnetic light is then channelled and diffracted using diffraction grating to separate the difference of wavelengths.

In the Synchrotron it is the diffraction of the light emitted from the electrons that is used to focus onto crystallised proteins to determine the structure.

This process is called crystallography and involves the diffraction of the beam that was transmitted onto the protein. The angle and intensity of the diffraction is then recorded and used to determine the overall protein structure. The synchrotron has helped us understand the relationship between physics, chemistry and biology and how they combine to achieve scientific discoveries.

Acknowledgments

CXS

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The University of Melbourne

Australian Synchrotron

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We had a fantastic time!

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