PHABLABS 4.0

PHOTONICS WORKSHOP

MAKING HOLOGRAMS

Display holography in industry

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PROPERTIES OF THIS WORKSHOP

SUMMARY:

Spectrometry allows us to see what colours of light are present in our source, the students will create a simple spectrometer from 3D-printed material, a diffraction grating and some cellotape.

TARGET AUDIENCE:

Young entrepreneurs (+18 years old)

SUGGESTED TIME PLANNING: (Total: 90 minutes - 3h)

Timing in minutes	activity
0 - 10	Introduction to laser safety
10 - 15	The use of holography in industry
15 - 20	How does a hologram work?
20 - 80	Making a laser hologram
80 - 90	Finishing the hologram

TOOLS:

Holography kit from intergraf.

ESTIMATED COST:

€30

Step 1: Intoduction

Introduction to Laser Safety

In this activity we will be using a red laser diode, similar to the type of laser found in a barcode scanner, DVD player or laser pointer, to make a hologram. Because laser beams tend not to spread out, they can travel directly into our eye and be focused to a very bright spot on the retina which can damage the eye. It is very important NEVER TO LOOK DOWN A LASER BEAM! And of course - NEVER let anyone in the workshop point a laser beam at someone else! We recommend FAB LAB staff supervise the setting up of the lasers. We recommend putting a card in front of the lasers so that you can anticipate where the beam will go when you turn it on so that you can control the beams carefully. The laser that comes with the kit has a safety warning, please read it carefully before operating it. Once you unscrew the lens from the front of the laser, the beam spreads out and is less dangerous.

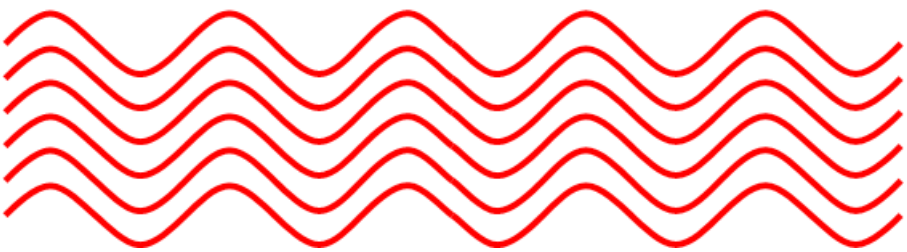
The uses of holography in Industry

We are going to use laser technology to make a hologram. Holograms are three dimensional (3D) images made with lasers. Holograms are found on banknotes, bank cards (as shown below), and on many different types of items for authentication and security purposes. Holograms are also effective marketing tools, the display Market alone will be worth $3.57 Billion by 2020. Lastly, holography can be used in museums to display copies of objects instead of the objects themselves. The figure below shows a full colour hologram of a Faberge Egg designed to be displayed in a Museum, instead of the egg. There is a general misconception about what is and isn't a hologram and this workshop should clarify the difference between laser produced holography, and 3D projected displays.

A security hologram on a bank card & hologram of a Faberge egg (Optoclone)

The Light theory behind 'Making Holograms'

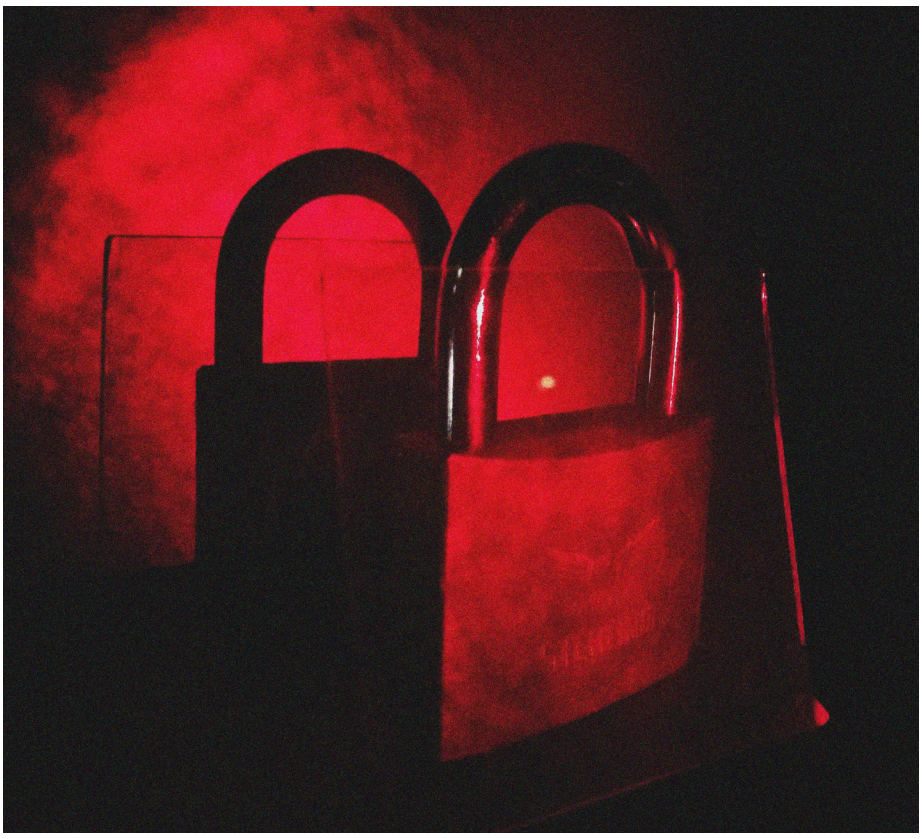
I. Light travels in waves:



Laser light

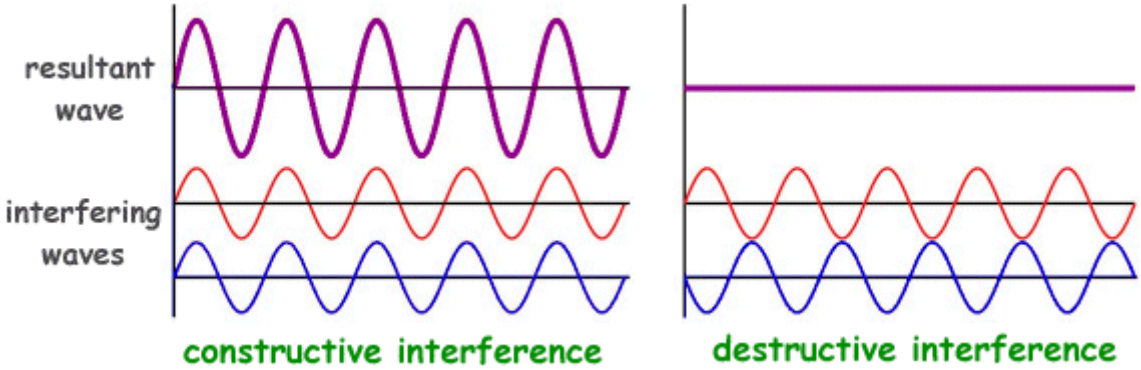
Ii. Laser light can be made to spread out. Demonstrate how the laser light can be made to spread out, by removing the lens on the diode laser in the kit. Diode laser beams are elliptically shaped and spread the beam out, the lens on the front of the laser collimates it, or prevents it from spreading out.

Iii. Diffraction and Interference: While the beam is spread out (in the dark) shine the beam of light onto something and ask the entrepreneurs to describe it. Hopefully they will notice a speckle pattern, tiny dots of light and dark that are nanometers (or billionths of a metre) apart. (A nanometer is how long your hair grows in 1 second!) It's this pattern of light and dark, known as interference, which is used to make a hologram. We can only see this pattern with laser light.

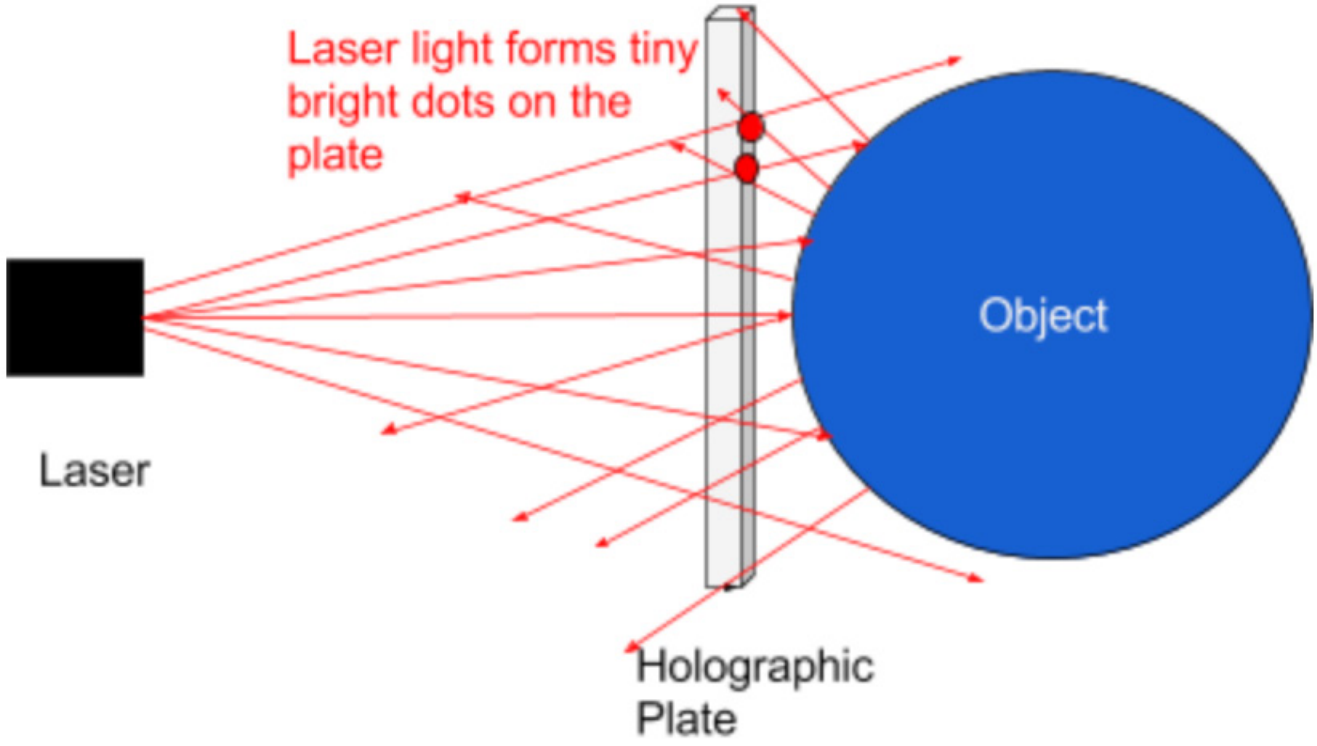


Laser speckle and interference

Light from the laser travels through the transparent holographic plate and reflects off an object back onto the holographic plate. Where the laser beams cross over at the plate, constructive or destructive interference occurs. Constructive interference causes bright areas of light, and destructive interference results in a dark area. The tiny dots of constructive interference cause tiny particles of silver in the holographic plate to blacken when developed. When you light the finished hologram with a torch, light reflects off those clumps of silver in the holographic plate in different directions, forming the final image you made your hologram of.



Superposition of waves



Light reflects off the object back onto the plate causing constructive and destructive interference: Bright points of light are recorded on the emulsion.

The silver halide in the emulsion responds to the light waves just like it responds to light waves in an ordinary photograph. When you develop the emulsion, parts of the emulsion that receive more intense light get darker, while those that receive less intense light stay a little lighter. These darker and lighter areas become the interference fringes.

Turning these fringes back into images requires light. The tiny, overlapping interference fringes can make the hologram so dark that it absorbs most of the light, letting very little pass through for image reconstruction. For this reason, processing holographic emulsion often requires bleaching.

Once a hologram is bleached, it is clear instead of dark. Its interference fringes still exist, but they have a different index of refraction - rather than a darker color. In a bleached hologram, variations in the index of refraction change how the light waves travel through and reflect off of the interference fringes.

Step 2: Parts list

Collect all materials for each participant. The holography kit can be ordered from www.integraf.com

Photonics Parts:

Holography kit:

3x laser diodes with collimating lenses and power supplies.
Holography plates
Holographic chemistry and developer trays
A green holographic safelight
(30 participants)

Developing Equipment:

Developer trays
Destillated water

Safety equipment:

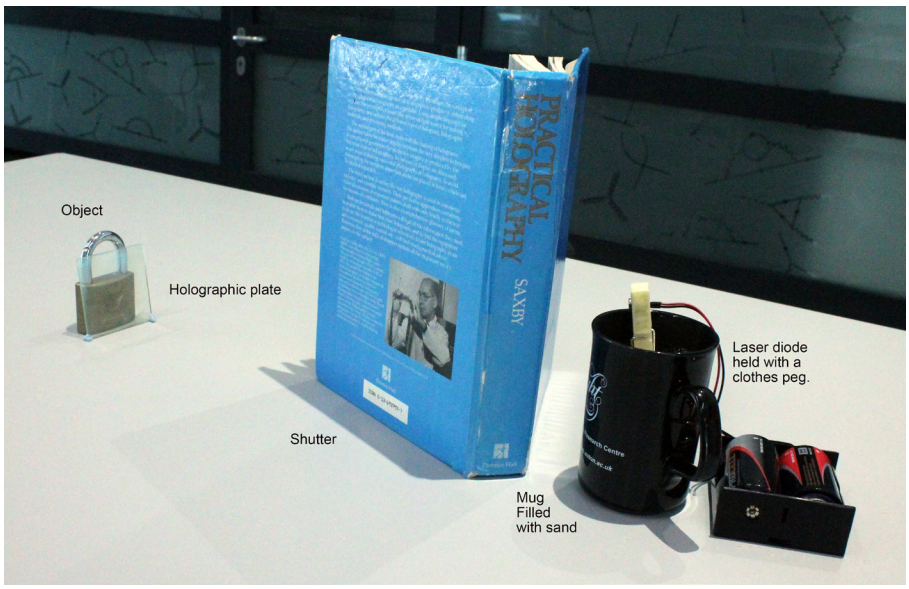
Lab coats (Min 2)
Rubber gloves/non-latex gloves

Other parts:

Mug
Sand
Heavy book
Blu Tak
Kitchen roll/kitchen disposable towel

Rubbish bag
Jug
Scissors
Sellotape
2-3 hair dryers to dry off holograms
Hot glue guns for participants to prepare their objects.
Suitable object to make holograms of; small shiny things:
eg. money, keys, nuts and bolts

Step 3: Making holograms



A holographic set up

1. Setting up your red laser diode and object:

With the Lights on:

1.1. Choose a suitable object to make a hologram of. The object we have chosen shown in our set up above, is a heavy, shiny lock, which is a very suitable object. Other objects, shown below, include keys, coins and nuts and bolts. These objects can be hot-glued onto something heavy; a brick, or a block of metal, to enable them to be put vertically in the path of the laser beam.

1.2 Make a firm base for your laser: fill one mug with sand (or more mugs depending on how many holography set ups you are going to have).

1.3 Clip a wooden clothes-peg carefully around the diode laser (holding it at the edges - don't put your fingers over the front of the laser as you may damage it) and push the peg and laser firmly into the sand.

Setting up laser

Place the mug approximately 30-40cm away from the object you are going to make a hologram of, as shown in figure 3 above.

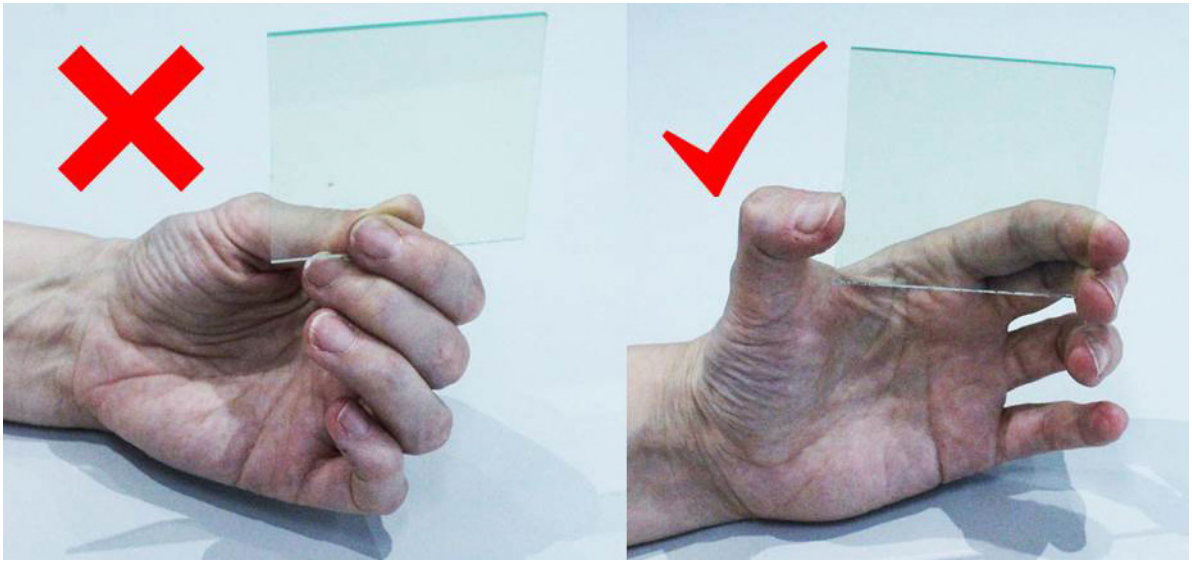
With the lights off:

1.4. Turn the laser diode on and light up the object fully with laser light. Hold a piece of white paper behind the object to help to check whether the object is fully lit. You should see a shadow of your object, surrounded by laser light. Reposition the mug with the laser until the object is well lit.

1.5. Once your object is fully illuminated, place a book in the path of the beam between the laser and object, removing the paper from your set up.

With the lights back on.

1.6. Next we need to show students how to hold the holographic plate, and how to identify which side of the plate has an emulsion on it.
Holding the plate: Please see Figure 5 below to see how to hold a holographic plate. ONLY EVER HOLD THE PLATE BY ITS EDGES, DON'T TOUCH THE EMULSION! (Or you'll end up with fingerprints permanently on the hologram). On one side of the plate there is an emulsion with tiny pieces of silver embedded in it that is sensitive to light, the other side is glass only. You can touch and clean the glass side, but never the emulsion side as shown in the photos below: (The glass side fogs up when you breathe on it).



How to hold the holographic plate.

Finding the emulsion side: Tell the students to breathe heavily on the holographic plate and keep the side that fogs up with their breath towards the laser beam, and the side that doesn't fog up towards the object. The glass side fogs up – the side of the plate with an emulsion coating does not. When the students are given a light-sensitive plate in the dark they will have to face a dim light source in order to do this eg. any crack of light coming under a door.

Breathe on the holographic plate to find the glass side that fogs up.

2. Shooting the Hologram

In the dark under green safelight.

2.1. Take 3 holographic plates out of their wrappers, remove any plastic edge strips which might be protecting the plate, and hand the plates to the students by the edges and. CLOSE THE BOX. (Students often turn lights on by mistake ruining all their plates). Remind students to breathe on their plate. Lean the hologram at an angle against the object (emulsion side which doesn't fog up – towards the object) and press a small (pea-sized) piece of Blu-tak at the two bottom corners of the plate to the table/bench to keep the plate firmly stable during exposure.

2.2. Allow 1 minute for the object to settle, and tell everyone in the room (and the next room) to hold still. Quietly in the dark.

2.3. Now, lift the book (which is acting like a camera shutter) 1-2 cm above the table while still blocking the laser light, and wait 10 seconds for the vibrations to subside. (Don't touch the table)

2.4. Lift the book all the way up, allowing the laser light to escape from under the book and fully light up the holographic plate and object. Hold for approximately 10 seconds then replace the book in front of the laser blocking out the light again. This is known as 'shooting' or 'exposing' the holographic plate.

2.5. Ask students to hand back their plates to you and put them back in a light tight box, remembering what order they were placed in the box so everyone knows whose holograms are whose.

Lights back on!!.

3. Developing the holograms

3.1. Preparing the Holographic Chemistry:
Mixing the chemistry will need to be done before the workshops. The chemicals for the workshop will arrive in boxes in powdered form, so you will need to prepare these before the workshops. You will need 3 plastic bottles/contains for the chemicals which should be mixed with distilled water. Two bottles will be needed to store the A and B holography developer and 1 bottle will be needed to store the mixed holographic bleach. The bleach can last for a couple of months in a cool environment, but the developer needs to be disposed of after the workshop.
Make sure you follow the safety advice in the instructions for mixing, storing and disposing of the chemicals for health and safety and environmental reasons. These chemicals are considered suitable for school use, although we recommend keeping the bottles of solution tightly closed and away from the young students. It would be best for you to do the developing, or supervise the students very closely while they are developing.

3.2 Put on a lab coat to protect your clothes, along with safety glasses and rubber gloves and process the exposed holographic plate according to instructions that accompany the JD-4 chemistry. (Please note the chemicals can drip and ruin expensive shoes).

Lights off after pouring out chemistry.

3.3 Place hologram emulsion-side-up in the developer together and, following the instructions provided with the developer, remove the holograms immediately after they are finished developing (or they will turn opaque). In order to mass-produce holograms place all three holograms in the same processing trays to process at once. Once the holograms are in the last 'washing' phase, let the students take their holograms out themselves. They will have to watch the process carefully so they can remember which holograms are theirs.

4. Drying the holograms

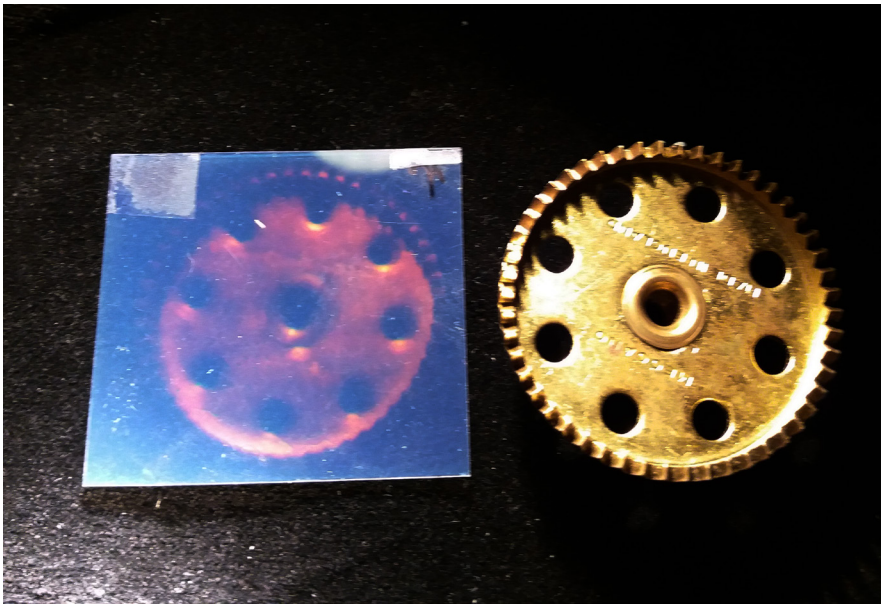
4.1 Once the holograms have been processed, ask students to dry them off with hair dryers (hold hair dryers at arm's length from the hologram and dry both sides - don't touch the emulsion).

5. Viewing your hologram

5.1 Aim a torch light at the glass side of the hologram. Rotate the hologram and tilt the hologram until you see a reddish colour object appear. You should see a hologram if the plate is dry.

5.2 If the plate is not yet dry - light the hologram from the back (emulsion side with the light shining towards you through the plate). See Figure below. The angle you light the hologram will depend on how much you tilted your hologram when you shot it.

Viewing a wet hologram



A good hologram with original object.

6. Troubleshooting

6.1 Practice your technique making holograms and get confident before trying this out with a small group of entrepreneurs, before working with a larger group! There are though hints/tips on how to work with big groups below. This activity is experimental. Each time you make holograms the results may be different due to vibration which will either make the holograms dimmer, or mean they don't show up at all. The following can cause problems; air-conditioning, the heat of the room, how much the students move

about, people touching the tables when the hologram is being made, trucks passing by the venue, doors slamming.

6.2 In the developer - If the plates don't turn black quickly, this means they needed more laser light exposure.

6.3 When the hologram is lit If there are any areas of darkness on the plates, this means there has been movement. If there are dark lines on the object, the object has moved. If there are dark lines or dark areas on the plate, then the plate moved.

7. Looking after the hologram.

Once the hologram is completely dry it can be wrapped either in the black paper it came in, in its original box, or in white paper. Information will be provided that can be printed off and given to students and this print out can be folded around the hologram.
Keep the hologram away from moisture or water.
The hologram can be painted black with spray paint to protect the emulsion. Spray the side that doesn't fog up (the emulsion side) to seal the hologram.

8. Logistics.

Once you have practiced making holograms, it can be simple, but working with a larger group of people can be a challenge. You will need to work with as small a group as possible when you are making holograms in the dark to prevent vibrations. We would recommend starting with a very small group of students to practice your workshop, eg. perhaps 6 people, then you will get an idea how to speed up the process considerably.

Once you are working with a larger group, we recommend splitting students into two groups A & B (ask the teacher to help with grouping to ensure the least disruption) and use two different rooms at the start of the workshop. Once a small group of students have made and developed their holograms they are able to instruct their peers and then the process speeds up. Ask students to work in pairs. Much of the workshop relies on verbal instruction and this age-group will find it difficult to follow what they have been told. Working in pairs will enable to process to go faster. Please see ideas below in the 'Extension' section for a further activity to keep group B working while Group A are making holograms.

Step 4: Extension activities

For a 3 hour-long workshop we advise framing the hologram. Pre-cut lengths of wood can be used, or the entrepreneurs can have to measure, and cut lengths of wood with a mitre saw to make the frame for their 2.5" x2.5" glass holograms with a 2mm thickness. The frames can then be glued together and given a cardboard backing. Secure the backing with staples or framing tape.

This second activity can be useful to explain to students the difference between two and three dimensional images. The activity can also be used while one group is making the hologram before groups swap over.

"Mobile Ghosts" A Smartphone Pepper's Ghost or 3D Projected image

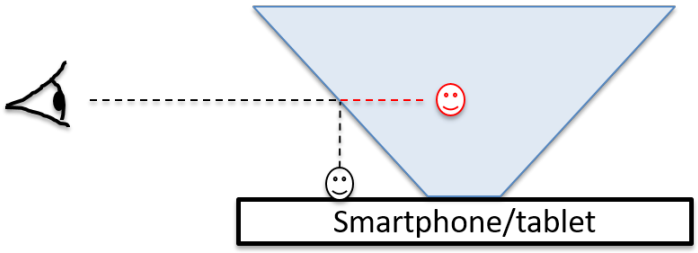
In this activity a smartphone is used, along with an inverted pyramid made out of acetate on top of the phone.

What is a Mobile Ghost?

More commonly known as Pepper's Ghost, the 'mobile ghost' is an optical illusion often used in haunted houses and concerts to make an image appear 3D and float in mid-air. They aren't holograms, but are often mistaken for holograms. Holograms are made with lasers and Pepper's ghosts are made with screens and a projected image.

The Light theory which makes this illusion:

A ghostly image is formed when rays of light from an object are reflected off one surface onto another reflective surface into our eyes. If the second reflective surface is transparent, part of the image is reflected and part is transmitted. The object appears slightly translucent and seems to float behind the transparent reflective surface. The 'Mobile Ghosts' are two dimensional (2D), but they look 3D because we see a slightly different image with both of our eyes. Our brain combines both views and interprets the object as being three dimensional.



Note: Depending on their age students may or may not have Smartphones. If they don't have a phone, ask the students to make a mobile ghost structure to take home, but to try it out on a phone that someone in the group has. You can also try this on a tablet or computer screen, but you'll need to scale up the size of the image.

Parts List. (not provided)

- scissors
- acetate sheets for templates
- sticky tape
- mobile phone.

1. Making your Mobile Ghost screen.

1.1 Photocopy the template below onto acetate. Cut out your template by cutting along the dashed lines on the acetate sheet shown in the Figure below.

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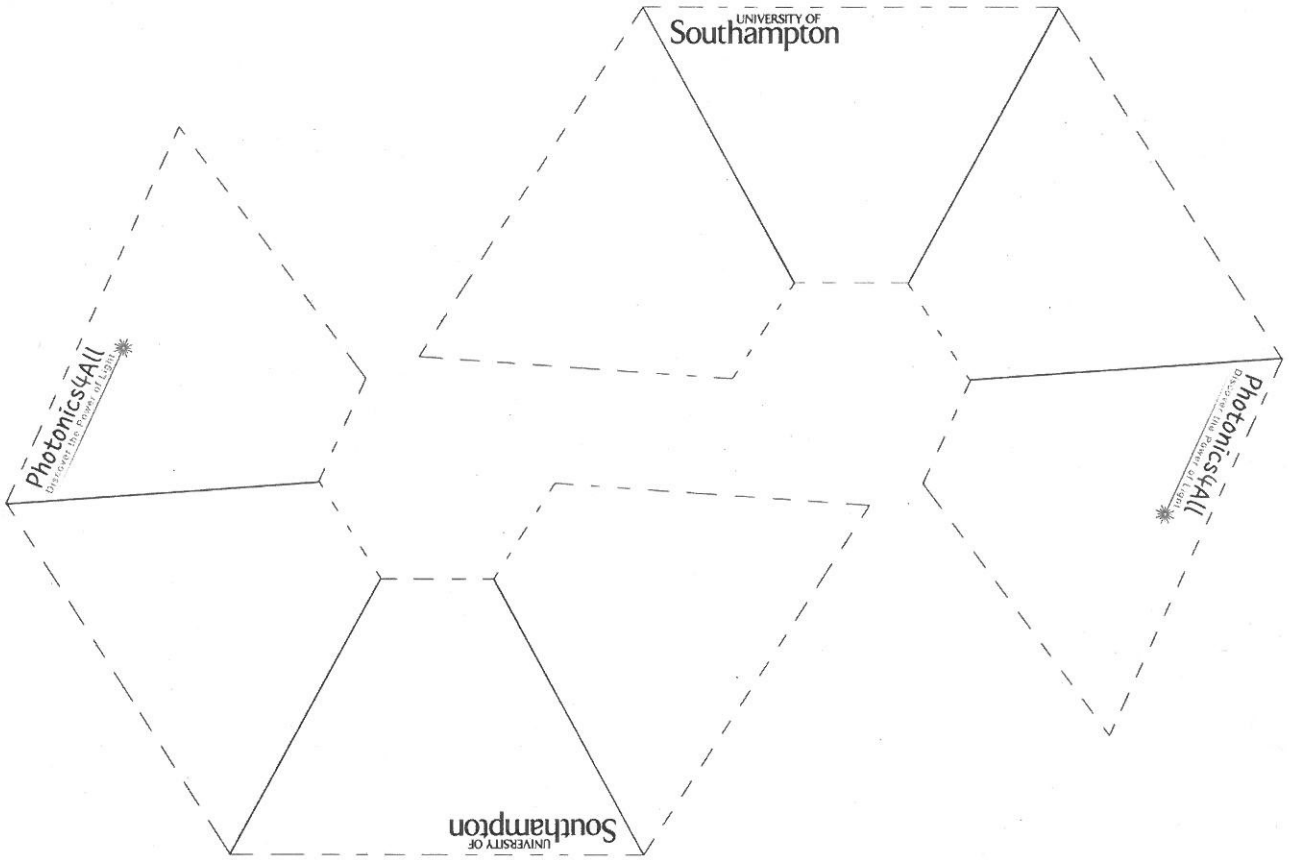
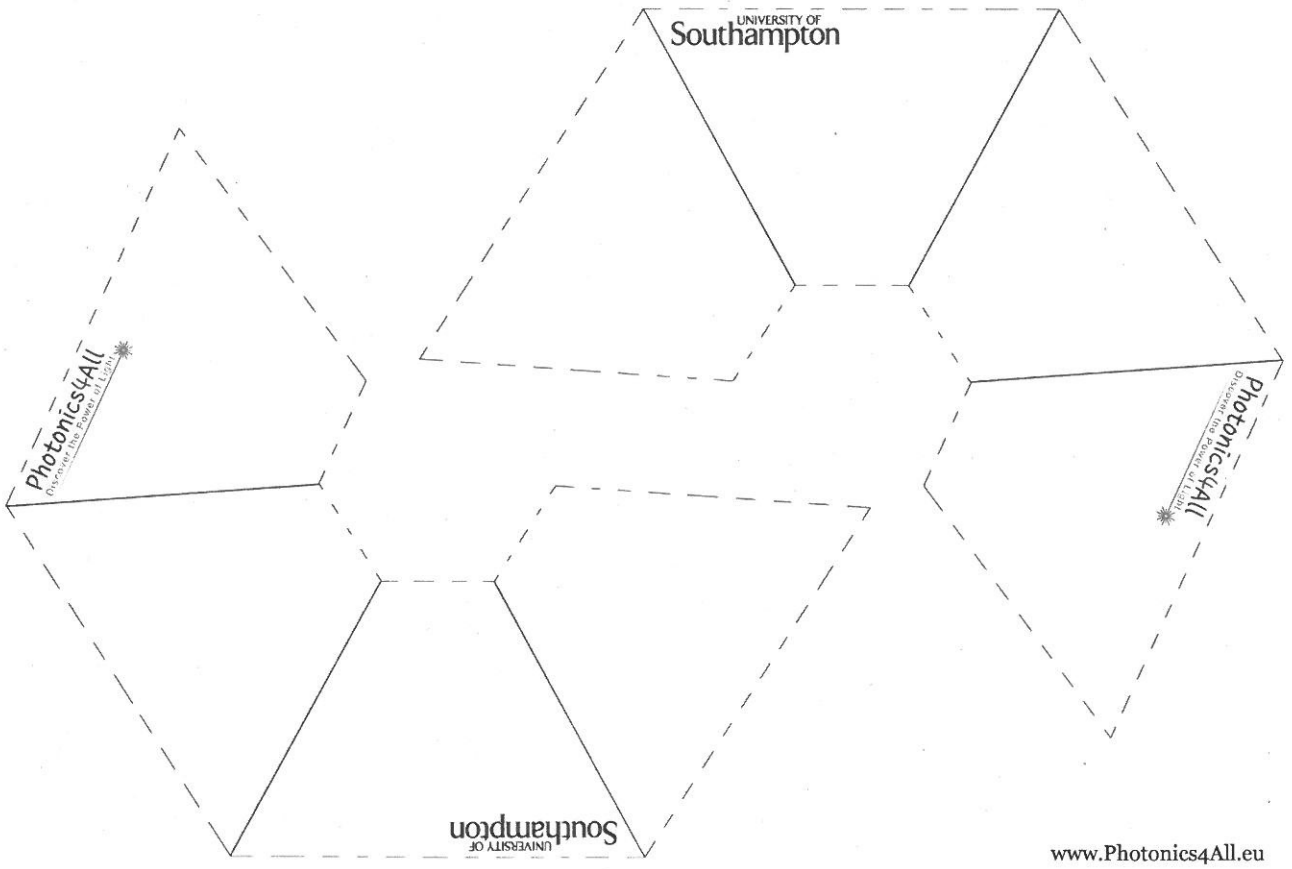
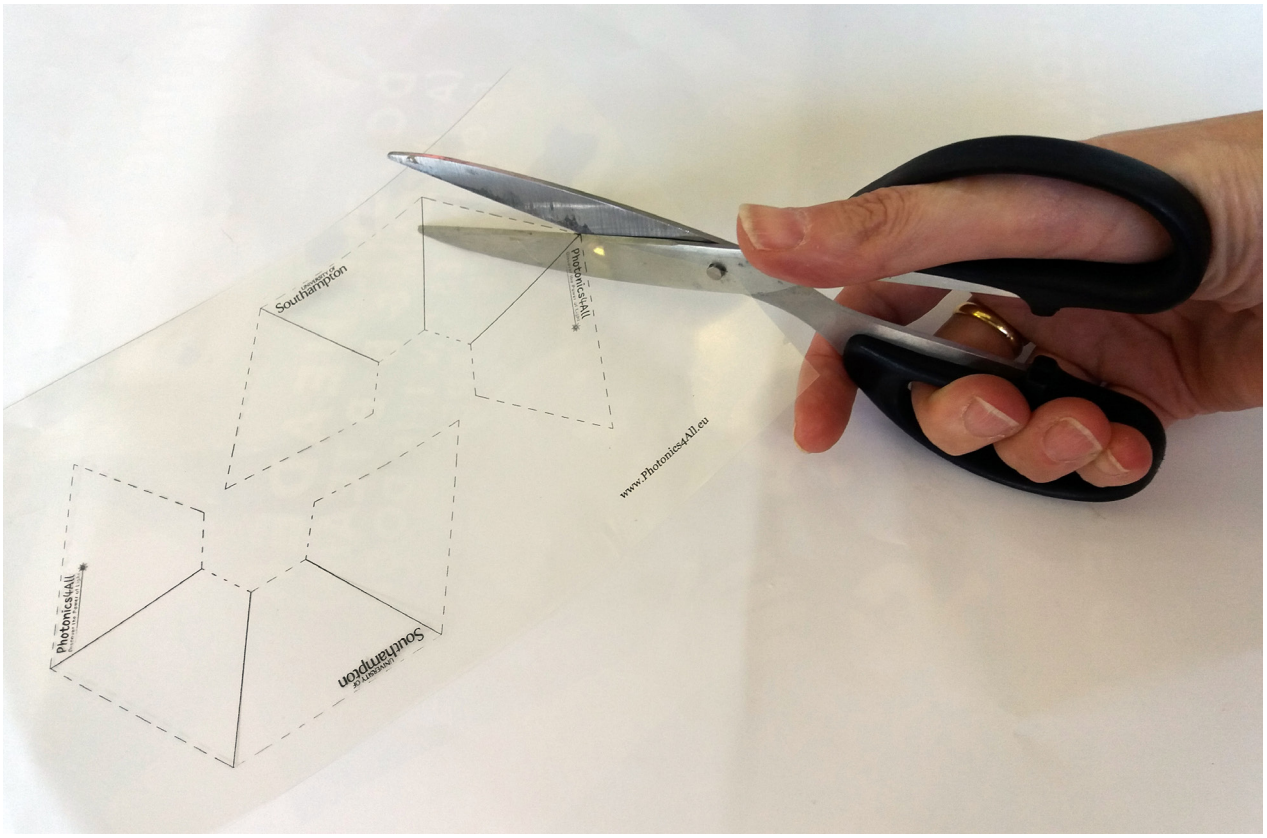
Mobile Ghost Template

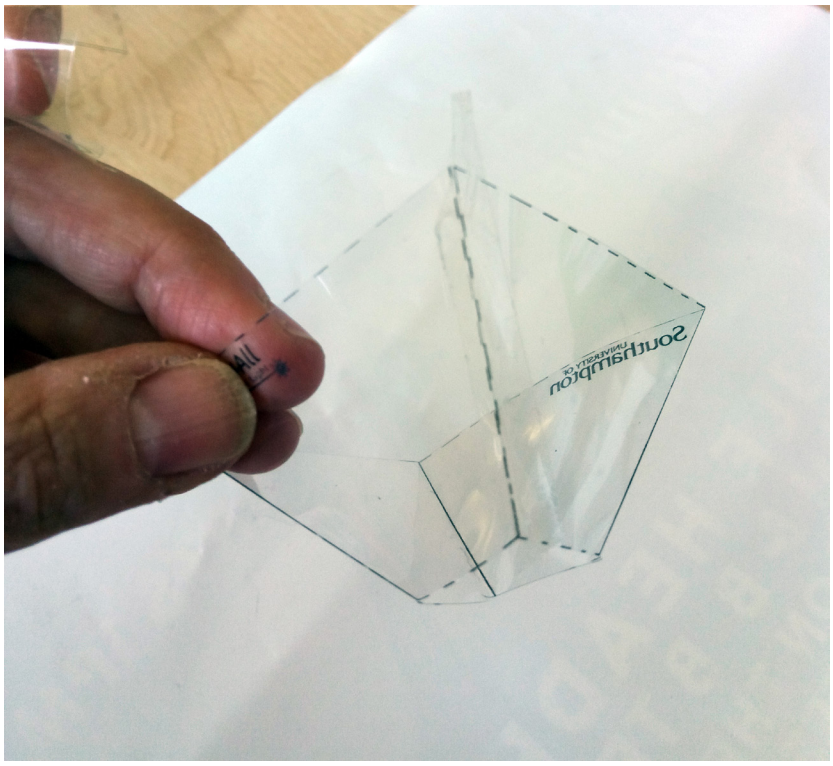






Cutting out Mobile Ghost template photocopied onto acetate.

1.2 Once you have cut out your shape, fold the acetate template along the dotted lines, folding all the sides inwards to make the inverted pyramid shape. Cut a length of tape in half so you have a small strip to connect the screen sides together as shown in the Figure below.



Fold and tape up one edge to complete the mobile ghost screen.

2. Viewing your Mobile Ghost

2.1 Download a ready-made Pepper's Ghost app such as "Hologram Pyramid Videos" from the Google Play store for Android, or the iTunes store for iOS.

2.2 Scan the QR code below for a quick link.

https://itunes.apple.com/us/app/hologram-pyramid-videos/id1100684856?mt=8https://play.google.com/store/apps/details?id=com.holapex.hologram.app&hl=en

2.3 If the FABLAB has an internet connection that the students can use ask them to search for Pepper's Ghost images. One can be found here: https://www.youtube.com/watch?v=XH_5WyKeq2U

2.4 Place your inverted pyramid onto the smartphone screen and see the image appear to be floating in the centre of your Mobile Ghost Screen.

Troubleshooting

If the floating animated image is difficult to see – turn the lights off in the room, or make sure that the image has a dark background.

Step 5: End result & conclusions

What we learned?

Entrepreneurs have revised some light theory that they already knew, ie. that light travels in straight lines, and it reflects off objects. They have been reminded of the difference between two and three dimensions. Participants have learned some new light theory and vocabulary such as 'interference' ie. the way that laser light forms tiny dots of light and that these bright areas can form an image in a holographic plate.

Workshop participants ave learned new skills making a hologram, working safely with a laser, and they have produced a mobile ghost. (A Pepper's Ghost with their mobile phones).

The participants have learned a new skill: they have learned how to make, develop and light a hologram to be able to view it. They may also have made a 'Mobile Ghost'. Not a hologram, but a 3D projected image. Holograms are made with lasers and require a bright light to illuminate them in order to be able to see the image. The mobile image requires an acetate surface to reflect from.

Concluding thoughts

There is an international shortage of people who know about Photonics, the Science of light, and who know how to make holograms. There are so many different ways holography can be used and we need more people to experiment with it. The laser technology you have used today has given you a lot of information that people who work in holography need to know. They need to be able to control and manipulate light, with a knowledge of interference and vibration issues in order to make holograms. Viewholographics made a hologram of CT medical scans of a mummy. The actual mummy was covered in bandages and you couldn't see the skull. The CT Scans provided 3D images from a complex x-ray image. Capturing the medical imaging techniques surgeons use to help them with complex surgery, archaeologists were able to explore the mummy without destroying it. This is one of the many interesting things we can do with holography.

PHABLABS 4.0

PHABLABS 4.0 is a European project where two major trends are combined into one powerful and ambitious innovation pathway for digitization of European industry:
On the one hand the growing awareness of photonics as an important innovation driver and a key enabling technology towards a better society, and on the other hand the exploding network of vibrant Fab Labs where next-generation practical skills-based learning using KETs is core but where photonics is currently lacking.

www.PHABLABS.eu

This workshop was set up by NUI Galway, Tissue optics & microcirculation imaging department, in close collaboration with Maker Space NUIG.

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ECOP European Centres for Outreach in Photonics