

This module is in the Energy and Change strand and is suitable for students working at levels 4-6

Lasers



Lasers – the stuff of science fiction or everyday life. Your students will determine which as they work through these activities.

They will develop an understanding of what lasers are and an appreciation of the many uses we employ them for on a daily basis. They will see how research into gravity wave detection makes use of the properties of lasers and observe a functioning interferometer.

At school they can take part in an internet web quest as a member of a UN committee investigating the benefits of lasers to humanity.

As their teacher you will find the assessment rubric and background information invaluable as a means of levelling your students progress.

Background Information

These sheets are to provide teachers with background information on this module, which may be passed on to their students.

Lasers

What are they?

The term laser is an acronym for **light amplification by stimulated emission of radiation**. Lasers control the way that energised atoms release photons. The light that they produce is **monochromatic** (i.e. It is of the one wavelength, colour) and **coherent** (i.e. All waves have crests and troughs at the same time. They are in phase. The photons have wave fronts that launch in unison.) The light is very **directional**. (i.e. A laser light has a very tight beam and is very strong and concentrated. Conventional light sources such as torches generally produce weak diffuse light.)

How are they produced?

There are many different types of laser, but they all share similar features.

In all lasers the lasing material is 'pumped' to excite the electrons in its atoms up to higher energy levels. Usually this is achieved with intense flashes of light or electrical discharges. This produces a high number of excited atoms, which is necessary for a laser to work efficiently.

Normally the electrons in atoms sit in the lowest allowable energy level (i.e. at their ground state). If you can excite so many atoms that there are more excited atoms than ground state atoms you achieve a **population inversion**.



Ground state



Excited state – population inversion

images from <http://www.colorado.edu/physics/2000/index.pl>

Just as an electron can absorb energy to get to an excited state, this energy will be emitted when the electron falls back down to its ground state. This **emitted energy** comes in the form of

photons (light energy). Two identical atoms with electrons in identical states will release photons with identical wavelengths. With a torch, all of the atoms in the globe's filament release their photons randomly. In lasers this photon emission is organised. This type of emission is called **stimulated emission**. The photon that any atom releases has a certain frequency that is dependent on the energy difference between the excited state and the lower energy state that it falls to. If this photon (possessing a certain energy and phase) should encounter another atom that has an electron in the same excited state, stimulated emission can occur. The first photon can stimulate or induce atomic emission such that the subsequent emitted photon (from the second atom) vibrates with the same frequency and direction as the incoming photon.

Another feature of lasers is a pair of **mirrors**, one at each end of the lasing medium. Photons, with a very specific wavelength and phase, reflect off the mirrors to travel back and forth through the lasing medium. In the process, they stimulate other electrons to fall down to a lower energy state and can cause the emission of more photons of the same wavelength and phase. A cascade effect occurs, and soon we have propagated many, many photons of the same wavelength and phase. The mirror at one end of the laser is "half-silvered," meaning it reflects some light and lets some light through. The light that makes it through is the laser light.

(More information on the basic principles and operation of lasers can be found at:

<http://repairfaq.cis.upenn.edu/sam/laserfaq.htm>

<http://science.howstuffworks.com/laser2.htm>

If you, or your students would like to do some experiments with those laser pointers that just sit in your desk drawers, then have a look at:

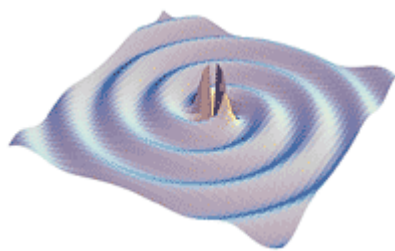
101+ experiments with laser pointers

http://www.metrologic.com/edu/global_info/101exp.asp

holography with cheap laser pointers

<http://www.holoworld.com/holo/diode1.html>)

Using lasers to help find gravity waves



Gravity waves are ripples in the fabric of space and time produced by violent events, such as the collision of two black holes or shockwaves from the cores of supernova explosions. Accelerating charges produces electromagnetic waves. Accelerating masses emits gravity waves. These ripples in the space-time fabric travel toward Earth, bringing with them information about their cataclysmic origins, as well as

invaluable clues as to the nature of gravity.

Albert Einstein predicted the existence of these gravitational waves in his 1916 general theory of relativity. Measurements have been made on the influence of gravity waves on a binary pulsar that agrees with his original predictions. They have not yet been detected directly however.

Gravity waves interact very weakly with matter. This means that when detected they will contain detailed information about their sources which is virtually unchanged during their travel to Earth. Currently we rely on electromagnetic information that we receive from space that is altered by the screening or scattering by intervening matter. Studying dark matter, which does not provide us with any electromagnetic information, is very difficult using current observational methods.

However this very weak interaction with matter also makes gravity waves difficult to detect. These waves are actually faint ripples in space-time, the four-dimensional world that Einstein created in his theories of special and general relativity. As a gravitational wave passes by, objects would change their length, but by only very small amounts. For example the distance from the sun to Earth would change by about one atomic diameter. This is an extremely small effect. Therefore very sensitive detectors are required.

One type of detector is the laser interferometer. As a gravity wave passes through the interferometer small changes in the two laser beams could be detected by a resulting interference pattern. These would observe the distance changes associated with gravitational waves by measuring small changes in the time needed for light to travel between suspended mirrors. Interferometers can be made more sensitive, in principle, by simply increasing the distance between the mirrors.

What benefits would arise from gravity wave detection?

- Detection of gravity waves would verify a fundamental prediction of General Relativity.
- Comparison of arrival times of light and gravity waves, from e.g. supernovae, would test Einstein's prediction that light and gravitational waves travel at the same speed, and that the graviton, the fundamental particle manifestation of these waves, has zero rest mass.
- Measurements could verify or refute the prediction of General Relativity that the waves only change distances perpendicular to the direction of propagation.

Benefits for astronomy may be just as profound as when we began to observe the heavens with instruments other than optical telescopes. By using radio telescopes, X-ray telescopes, infrared telescopes etc we were able to observe radiations from the complete electromagnetic spectrum. This gave us completely fresh information about the universe that changed our image of it. Detection of gravity waves will provide us with a completely new source of information that has the potential to foster yet another revolution in our growing understanding of the universe.

(The following Internet sites can provide you with additional information on this subject:

<http://www.gravity.uwa.edu.au/>

http://www.ligo.caltech.edu/LIGO_web/PR/scripts/facts.html

http://whatis.techtarget.com/definition/0,,sid9_gci773187,00.html

<http://lisa.jpl.nasa.gov/grav/gravmain.html>

<http://www.physicscentral.com/action/action-02-8-print.html>)



SCHOOL BASED ACTIVITY

**Before or after GDC visit**

These sheets describe a web based activity that students should undertake at school, in order to add to their work done while on site. To enable easier navigation to the provided links, these sheets are on the Internet at <http://users.tpg.com.au/users/rmeagher/laser/>

A laser weapon of mass destruction!

An evil doctor has held the world to ransom with an orbiting laser directed at major cities. He had threatened to use it if he did not receive a large sum of money.

Luckily for the world a British secret agent foiled the evil doctors plans! However the aftermath of the scare has created a population fearful of lasers. The United Nations intends to ban the use of ALL lasers.

You are a member of a committee that is to advise the UN on the matter, before voting occurs.

The committee consists of:

- a medical expert
- a communications/ computer expert
- a research scientist
- a military expert
- a graphic artist
- a stage and recording star, and a
- a member of the general public
- an engineer

As one of the committee members, you have been given the task of collecting information about the benefits of using lasers in your life. You must then prepare a presentation, along with the other members of your committee, for the UN council. The purpose of this report is to convince the council that lasers are an important part to our lives, and if banned people would be worse off.

Your presentation is a group presentation. As a group you must convince the UN council (i.e. your class) that the conclusions you have arrived at on the issue of the use of lasers are the correct ones. To do this, you will have to present to the council a comprehensive summary of the findings of each of the committee members. You must explain to the council the conclusions you have come to as a group, justifying each of these conclusions.

This presentation must be presented in as professional a manner as possible and should be at least 10 minutes in length. A PowerPoint presentation or at least the inclusion of overheads should be considered. Remember that even with audio and visual aids YOU must still speak to the audience. At the end of the presentation, you must be prepared to answer questions from the UN council members.

The following links will be useful to you during your research, but are by no means the only sources of information available to you:

[The Laser Adventure](http://stwi.weizmann.ac.il/Lasers/laserweb/Labs/Labindex.htm) <http://stwi.weizmann.ac.il/Lasers/laserweb/Labs/Labindex.htm>
[Applications of Lasers at Encyclopedia.com 2002](http://www.encyclopedia.com/html/section/laser_applicationsoflasers.asp)
http://www.encyclopedia.com/html/section/laser_applicationsoflasers.asp
[Lasers uses](http://outreach.rice.edu/~trslr/students/6science/web7z/#anchor489725) <http://outreach.rice.edu/~trslr/students/6science/web7z/#anchor489725>
[The Uses of Lasers in Today's Society](http://users.netconnect.com.au/~jackt/uses.html) <http://users.netconnect.com.au/~jackt/uses.html>
[Uses for Lasers](http://www.cyberstreet.com/laserone/lasers/uses.html) <http://www.cyberstreet.com/laserone/lasers/uses.html>
[Laser Applications page](http://stwi.weizmann.ac.il/Lasers/laserweb/Apps/App_frm.htm) http://stwi.weizmann.ac.il/Lasers/laserweb/Apps/App_frm.htm
[Applications of Lasers](http://laser.learning.center.ws/applications/) <http://laser.learning.center.ws/applications/>
[Laser Instruments and Applications](http://www.repairfaq.org/sam/laserlia.htm#liaint0) <http://www.repairfaq.org/sam/laserlia.htm#liaint0>
[Lasers - Everyday life](http://www.hugall.fsnet.co.uk/stemoptics/laexa.htm) <http://www.hugall.fsnet.co.uk/stemoptics/laexa.htm>
[Laser Applications](http://hyperphysics.phy-astr.gsu.edu/hbase/optmod/lasapp.html) <http://hyperphysics.phy-astr.gsu.edu/hbase/optmod/lasapp.html>
[Holography Lasers and Holograms](http://www.holoworld.com/holo/links.html) <http://www.holoworld.com/holo/links.html>
[Using Lasers to Study Our Atmosphere](http://oea.larc.nasa.gov/PAIS/LaserSensing.html) <http://oea.larc.nasa.gov/PAIS/LaserSensing.html>
[Lasers communication](http://essay.studyarea.com/old_essay/science/lasers.html) http://essay.studyarea.com/old_essay/science/lasers.html
[Lasers plastic surgery](http://www.sasakimd.com/lastversion/lasers.htm) <http://www.sasakimd.com/lastversion/lasers.htm>
[Laser for Haemorrhoids!!](http://www.hemorrhoid.net/laser.htm) <http://www.hemorrhoid.net/laser.htm>
[Information About Laser Eye Surgery](http://www.lasersurgeryforeyes.com/generalinfo.html) <http://www.lasersurgeryforeyes.com/generalinfo.html>
[LASIK Laser Eye Surgery - Procedure](http://www.1-lasik-laser-eye-surgery.com/lasik.html) <http://www.1-lasik-laser-eye-surgery.com/lasik.html>
[LASIK Laser Eye Surgery - Detailed Description and Pictures](http://www.lasik1.com/LASIK_Detailed.html) http://www.lasik1.com/LASIK_Detailed.html
[Today's Laser Eye Surgery Treatment Options](http://www.best-ranking.com/general.html) <http://www.best-ranking.com/general.html>





SITE ACTIVITY



Notes and Recording

This sheet is for students to record their results and observations during various activities.

Yes, lasers are the weapons of choice for all sci-fi heroes but they have many more down to Earth uses as well.

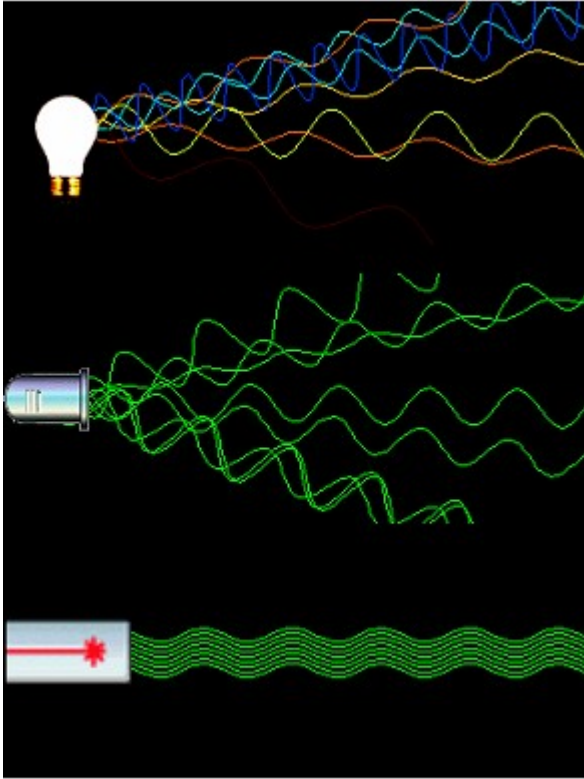


Images from <http://www.colorado.edu/physics/2000/index.pl>

Your CD players, DVDs, and game consoles all make use of lasers. Every time something is scanned at a supermarket a laser does the scanning. If you have a vision defect that can be repaired by reshaping your cornea, a laser will do the job. The spectacular light shows that you see at concerts most likely use laser light. Dentists and surgeons all use lasers regularly. And research work, such as gravity wave detection, makes use of lasers and their properties.

What makes laser light so useful? Just what are lasers anyway?

Reference books will tell you that the word 'laser' is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. You can see why we'd prefer to call them LASERS! You probably use many other acronyms each day without being aware of it. (How many do you know?) The acronym tells us that lasers operate by amplifying light. To understand lasers you'll need to know something about different light sources.



images from

<http://www.colorado.edu/physics/2000/index.pl>

White light from an normal light globe (ie incandescent) consists of:

- many different wavelengths of light,
- with various amplitudes,
- all going in different directions.

Monochromatic light (light of one colour) from a stage light consists of:

- light of only one wavelength,
- but the waves are out of phase (i.e. their crests don't line up),
- and they are travelling in many directions.

Laser light consists of:

- light of one wavelength,
- that is in phase (i.e. the crests line up. Waves that are in phase are called coherent.),
- and travelling together in one direction.

2. Because it is so ordered we can control laser light extremely well. That is why we can use lasers to do so many things. Because of its properties, what advantages do you think laser light would have over other forms of light?

Interference

When two waves pass through the same point at the same time they will interact with each other. Sometimes they will make a larger wave. This is known as constructive interference. Sometimes they will produce a smaller wave, or even cancel each other. This is known as destructive interference.

The diagrams below represent wave crests travelling toward each other. In both cases the crest is exactly the same length and height. Predict what will happen in each case as the crests pass through each other.

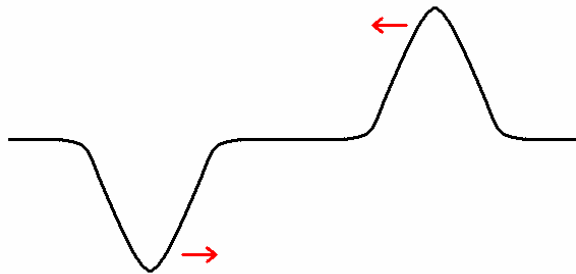
3.

A



Prediction:

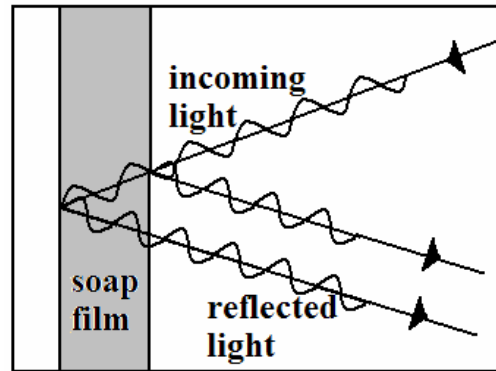
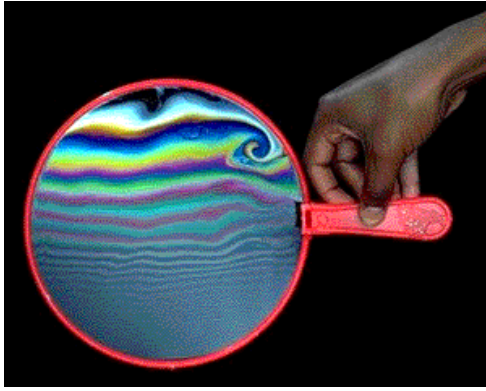
B



Prediction:

Visible light has very short wavelengths. Lengths of coloured light's waves are between 0.00000035m to 0.00000075m (i.e. 350nm to 750nm). If light undergoes constructive interference the results will be brighter light. If it undergoes destructive interference the result will be less bright, or no light.

When you look at the patterns in a soap bubble or oil film, you are seeing interference patterns. Some of the light that hits the soap bubble (or oil film) reflects off its top surface. Some of the light passes through the soap (or oil) and is reflected off its bottom surface. When these two reflected beams of light interact, they won't necessarily be in phase, since they have travelled slightly different distances. Depending on the wavelength of the light, the interference will be constructive (bright) or destructive (dark).



4. Can you think of the reason why the dark and light bands get closer together toward the bottom of the bubble?

Interferometers are devices that make use of these interference patterns. There is a model, of the one being used to detect gravity waves, on display in the GDC. (Exhibit #35). Move to it and make the following observations.

5. Draw a simple labelled diagram of the interferometer.

6. What are the functions of each component of the interferometer? (Ask your teacher or guide.)

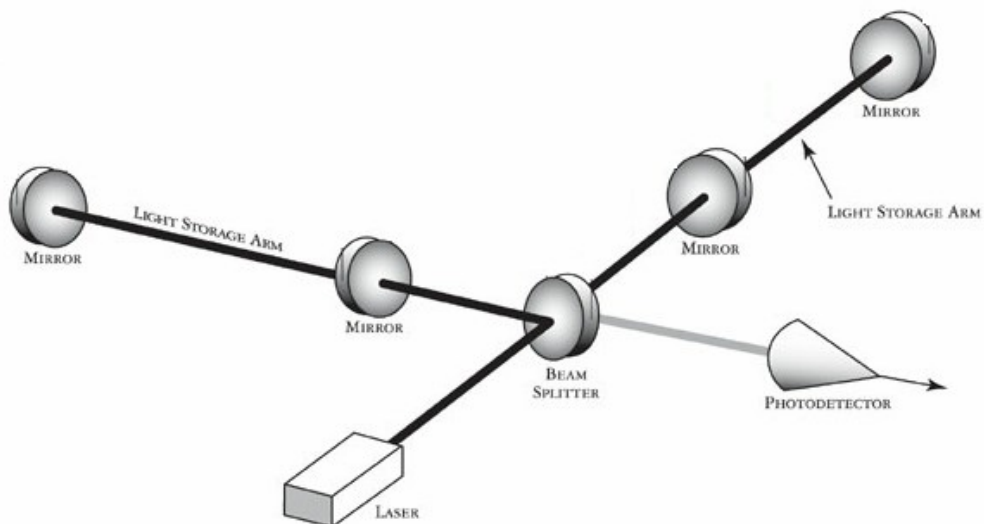
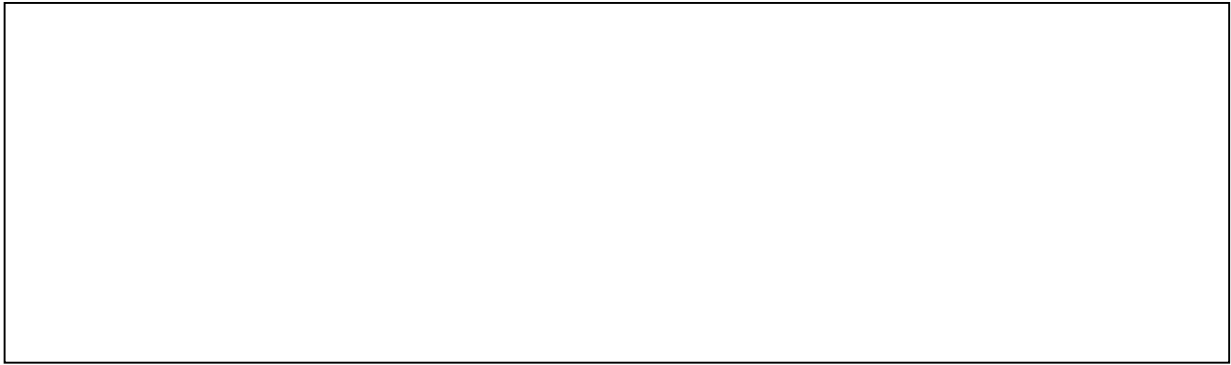
7. Gently tap the table, and describe what is observed at the detector. What effect did the tapping have on the distance apart the mirrors are?

8. In your group discuss what was observed. Explain what you think caused this observation.

Einstein predicted that when objects are accelerated, or when strong gravitational fields interact dynamically, that gravity waves will result. Likely sources for these waves would include supernovae and the collision or merging of objects like neutrino stars and black holes. These phenomena should result in extremely intense gravity waves.

But even these gravitational waves produce only weak forces by common standards. Passing through the Earth, they could move objects, but only by 1/10,000 the width of a proton, and for less than ten milliseconds.

9. How could an interferometer make use of these small movements and be used to detect gravity waves? (Hint think of the interference between the waves)





TEACHER AND/OR STUDENT USE



Rubric

These sheets are for teachers and students to assist in the levelling of student work completed while doing the 'Light and Lasers' module.

Overarching Learning Outcomes

There are opportunities within the activities in this package for students to demonstrate the following outcomes:

OLO 1

Students use language to understand, develop and communicate ideas and information and interact with others.

OLO 2

Students select, integrate and apply numerical and spatial concepts and techniques.

OLO 3

Students recognise when and what information is needed, locate and obtain it from a range of sources and evaluate, use and share it with others.

OLO 5

Students Describe and reason about patterns, structures and relationships in order to understand, interpret, justify and make predictions.

OLO 7

Students understand and appreciate the physical, biological and technological world and have the knowledge and skills to make decisions in relation to it.

OLO 10

Students participate in creative activity of their own and understand and engage with the artistic, cultural and intellectual work of others.

OLO 12

Students are self-motivated and confident in their approach to learning and are able to work individually and collaboratively.

Science Conceptual Strand – Energy and Change

These activities could be used to assist you in the levelling of your students in the ‘Energy & Change’ conceptual strand.

The following pointers could be used to determine the level at which your students have performed the activities.

Level		Pointer/s	Demonstrated
EC3	The student understands patterns of energy use and some types of energy transfer.	<ul style="list-style-type: none"> can recognise different sources of light energy 	
EC4	The student understands that energy interacts differently with different substances and that this can affect the use and transfer of energy.	<ul style="list-style-type: none"> can recognise that light energy can interact with other light energy and form patterns 	
EC5	The student understands models and concepts used to explain the transfer of energy in an energy interaction.	<ul style="list-style-type: none"> can use diagrams and the wave model to represent reflection and interference of light waves 	
EC6	The student understands the principles and concepts used to explain the transfer and transformation of energy that occurs in energy systems	<ul style="list-style-type: none"> can make generalisations on the behaviour of light based on their understandings can apply models and principles to explain the effect of changes to the interferometer 	

This sheet could be reproduced and provided to your students before they conduct the activities, or used by you to assess their performance, once the activities have been completed.