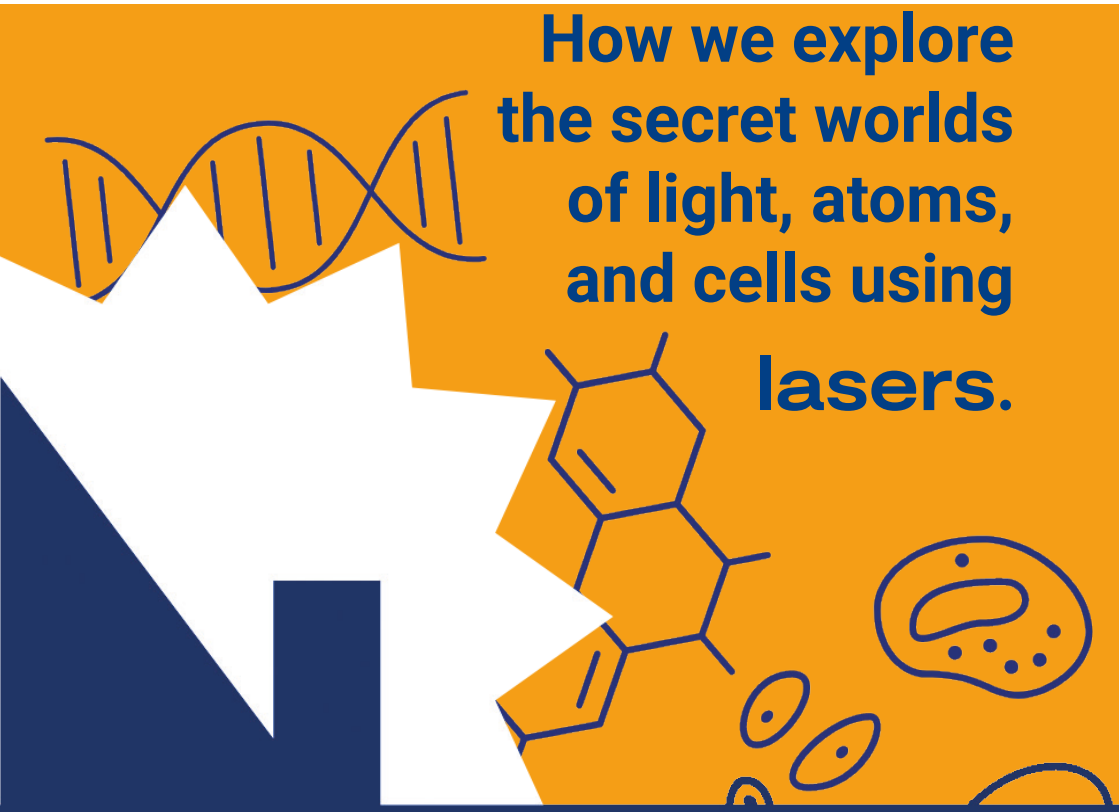
Ultrafast LASERS



How we explore the secret worlds of light, atoms, and cells using lasers.

UK Research and Innovation

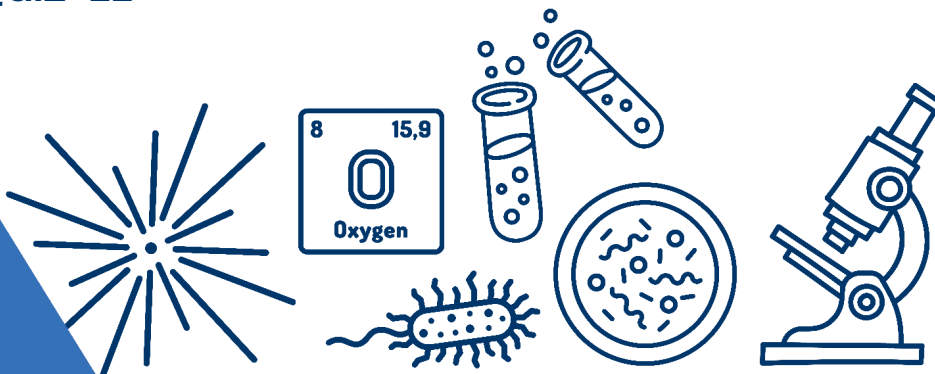
SCAN ME

Booklet created by:
Megan Pritchard
Central Laser Facility
Communications
Student

https://stfccareers.co.uk/students/

UK Research and Innovation

Contents

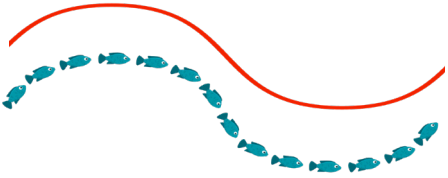


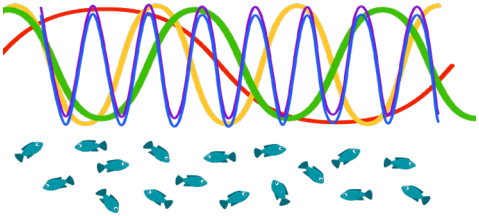
What is a Laser?

LASER stands for 'Light Amplification by Stimulated Emission of Radiation'

Lasers produce a special and rare type of light that can't be found in nature. The first laser was built in 1960!

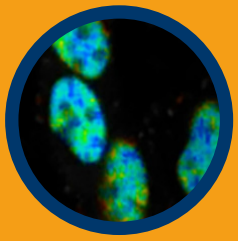
The light from a laser is made up of similar colours and moves together in a formation...





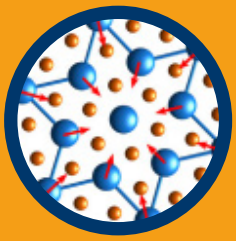
...while a lot of the light around you is much more jumbled up with very different colours!

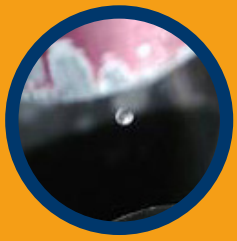
Some lasers are especially good at acting as magnifying glasses to help us see things like:



Cells from plants or animals

The structure of materials





Droplets in the air

The *Central Laser Facility* has three such lasers...

Artemis uses extreme ultraviolet light (more purple than purple!) to find out more about materials and their properties.

Ultra has a whole variety of colours to help scientists study processes between molecules in both chemistry and biology.

Octopus is a collection of laser-based imaging techniques, including super powerful microscopes!

We are here!

Now let's get into the science. Introducing...

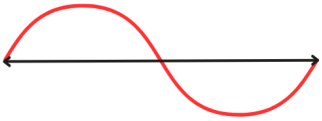
The ELECTROMAGNETIC SPECTRUM

There are so many different colours of light!

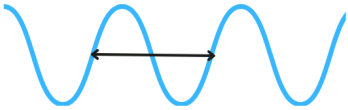
Some of them we can see, like red and blue. But other colours exist that are invisible to us – more red than we can imagine, or more violet.

Light is made of waves.

Red waves are longer

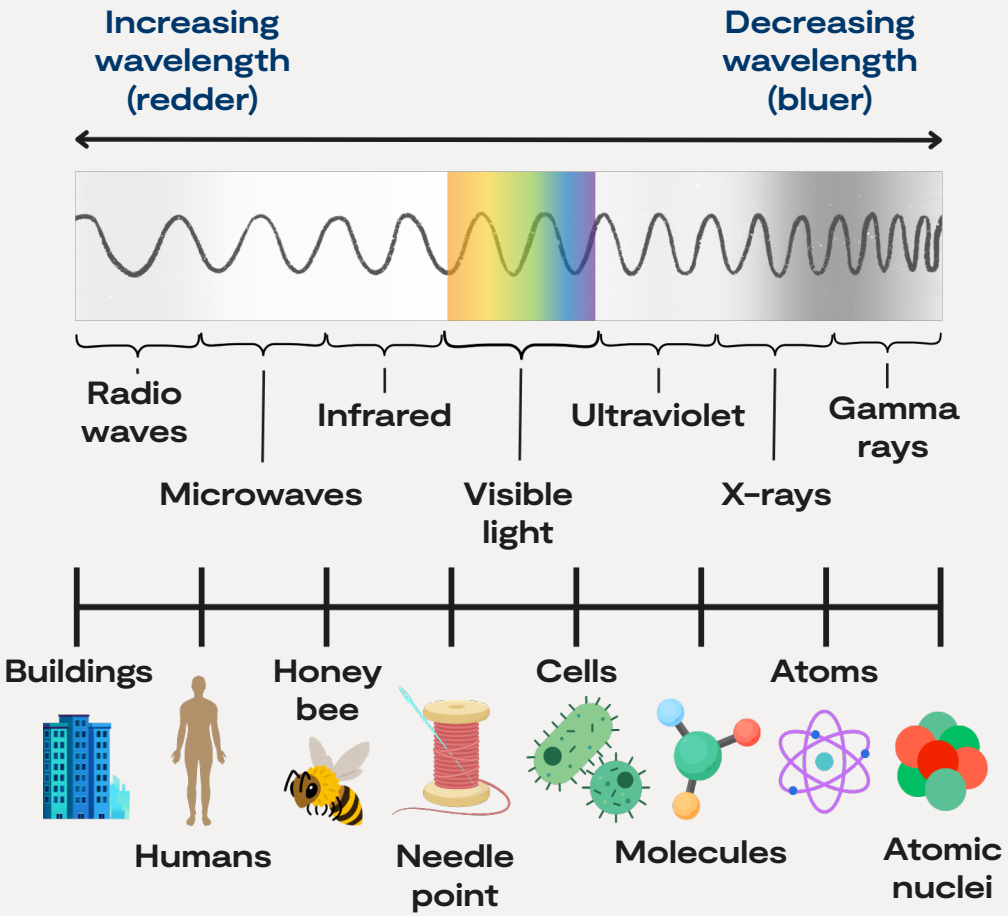


Blue waves are shorter



We call this length measurement a wavelength.

There is a huge range of different wavelengths and colours of light. This the **electromagnetic spectrum**. It ranges all the way from radio signals that we use to communicate around the world, to gamma rays that are emitted from radioactive samples!



Radio waves can be a KILOMETRE long...

...while gamma rays can be 1 TRILLIONTH of a metre!

Laser Imaging

A slightly unconventional way of taking pictures

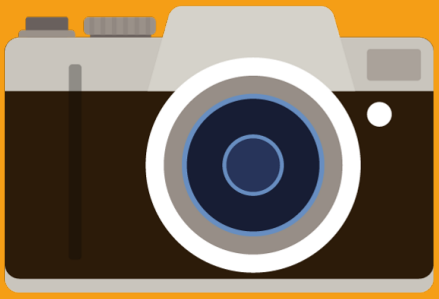
Light can carry a lot of information. When you see objects around you...

Trees

Buildings

People

...it's actually your brain making these pictures without you thinking about it. It does this by watching the way light bends and scatters when it hits objects!



A camera works in the same way, taking in the scattered light and turning this data into an image we can recognise.

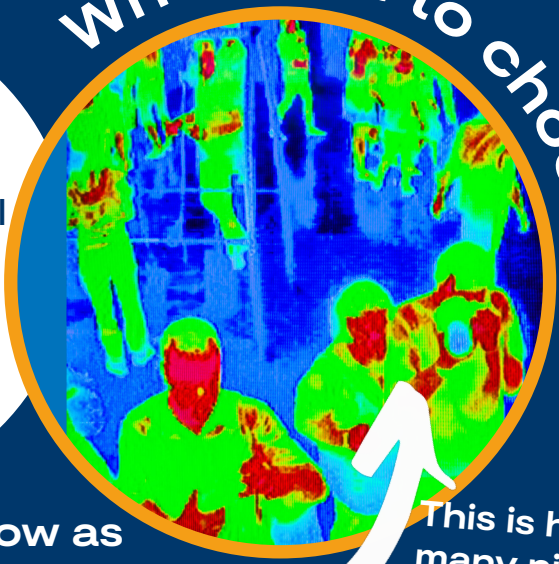
Lasers bounce and scatter off objects they hit.

We can then use detectors to 'read' the way the light scatters to tell us about the object!

What light to choose?

Infrared light can be used to see heat!

Detectors within thermal cameras take in scattered infrared light and converts it into colours our brains can recognise.



Hot areas show as red, while cool areas show as blue!

This is how many night vision goggles work!

Remember how blue and purple waves are shorter than red ones? Ultraviolet waves are even smaller! This means they can squeeze into the gaps between atoms and find out what's inside a crystal or stucture. This makes them amazing at imaging!

Did you know?

Many animals see more colours than we do. Some birds and insects can see ultraviolet, and some creatures such as the mantis shrimp have over 5 times the amount of colour receptors as we do!

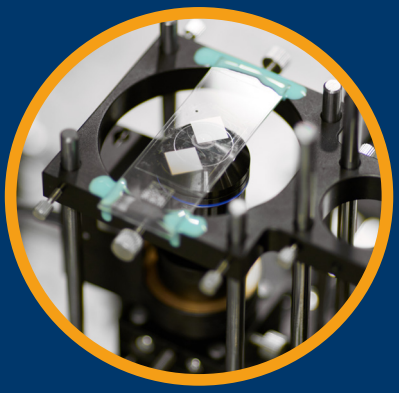
Microscopy

The study of very small objects

A microscope is a piece of equipment that allows us to see objects that the naked human eye usually can't. Many microscopes work just like cameras and watch how light bends and scatters when it hits an object.

But microscopes have one extra step. Instead of just focusing the light to show us the image, they cleverly use mirrors and lenses to bend the light just a bit more to magnify it. This tricks our brains into seeing an image that is **much larger** than the actual object!

Some microscopes use particles instead of light! As particles bounce off objects in the same way light does, they work just as well. In fact, they are often even better!



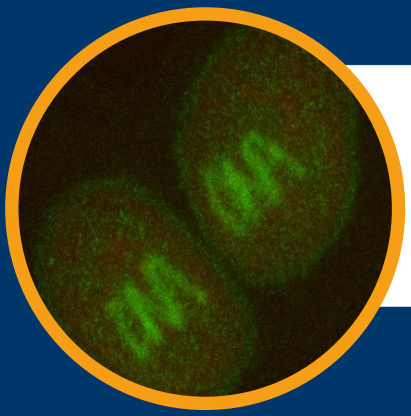
OPTICAL MICROSCOPES

Use light, mirrors, and lenses.

ELECTRON MICROSCOPES

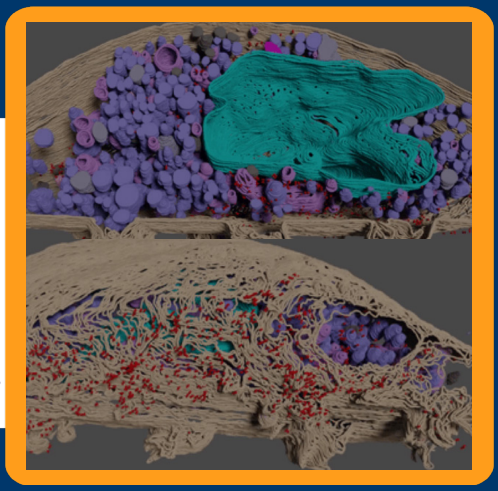
Use a beam of tiny particles and 'electron optics' to see even smaller objects!

Microscopes in Action



We can use fluorescent light to tag areas of an object we want to study. These cells have 'DNA' written on their surface!

We can make 3D images of objects by scanning them as lots of 2D slices! We then put all the slices together to make it 3D. This image shows a cell which is infected (the red dots!).

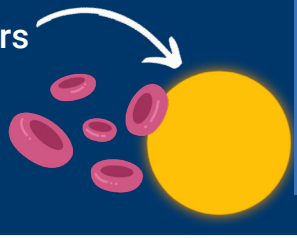


We can lock particles in the air like a tractor beam! This technique, called 'optical trapping', uses the forces in a laser beam to suspend droplets and particles in the air. We can even move them around as if we're holding them with tweezers.

Spectroscopy

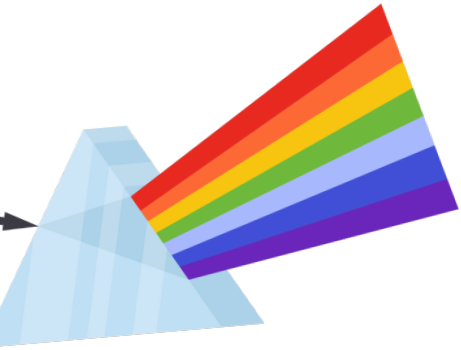
A different way of using light to see

How can we know exactly what a star light-years away is made of? How can we know what elements are in the building blocks of life, like proteins? The answer is: spectroscopy.



If you think of burning a material, you might picture the flame to be orange. But this isn't always true: copper burns blue-green, for instance, while sodium burns yellow.

Different materials will give off slightly different colours, which we can use as a simple identification system!



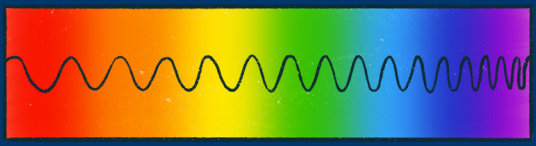
This is the idea behind a technique scientists use called spectroscopy.

It literally means 'looking at a spectrum' - in this case, the spectrum of light!

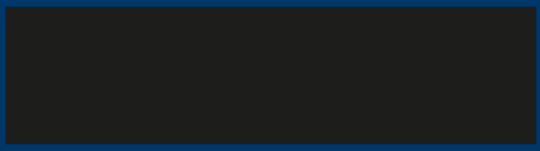
We shine lasers on an object to make it interact with light.

Each type of compound or material will interact with laser light in a unique way. We use this as a sort of fingerprinting system, or to tell us how materials behave. Spectroscopy commonly focuses on what colours of light an object interacts with - we can then map these colours on a spectrum.

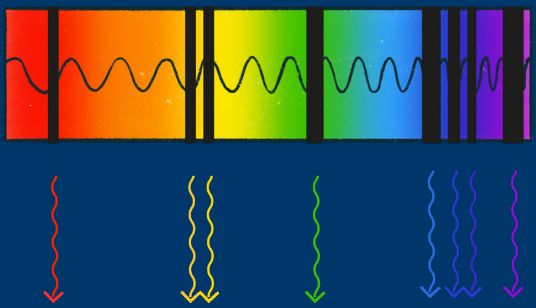
Colours within the light shone on a sample:



If all light was absorbed, it would look like this:



Here, only some colours are absorbed:



We call this an **ABSORPTION SPECTRUM**

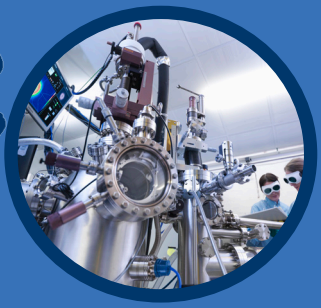
https://www.clf.stfc.ac.uk/Pages/home.aspx

Scan for more CLF!

Illustration by Helen Towrie
Impact and Engageme
Officer


PAPER
UNIVERSITY OF...

Artemis



Why are some materials magnetic? Why do others conduct electricity? At Artemis, fast laser pulses are used to learn why certain materials behave the way they do.

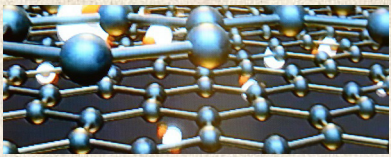
Artemis fires high-energy ultraviolet light at different materials and samples.

This gives the samples large amounts of energy that causes them to undergo chemical or physical changes.

Lasers like Artemis are used to take close-up images of extremely small objects like gas molecules. We can make very small details of our images even clearer by packing more energy into the laser. We're now adding even more energy to Artemis for this very reason!

ARTEMIS NEWS

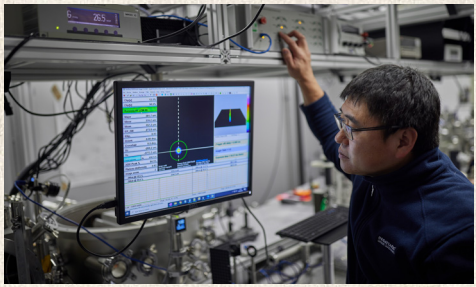
SMALL SCIENCE



2D materials, like graphene, are no thicker than a single layer of atoms - that's less than a billionth of a metre! Artemis studies the best properties of these unique materials, such as how they can be used to make better computers.

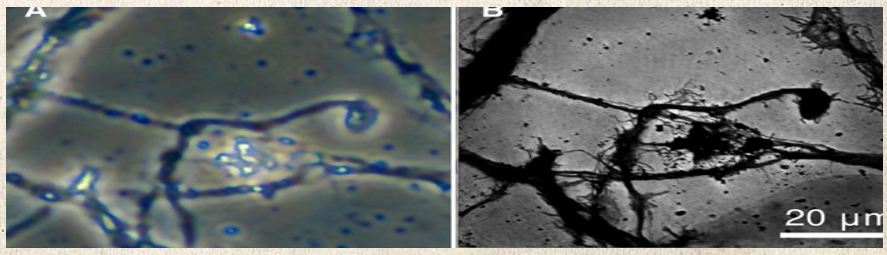
SECRET REACTIONS

Artemis' technology has been used to view quick and small chemical changes that previously we didn't have the capacity to measure. Amongst other things, this may help scientists make electronics more efficient!



BRAIN BIOLOGY

Researchers used Artemis to develop a technique that could image lab-grown mouse neurons in far more detail than traditional microscopes. By viewing neurons at this level of detail, we can begin to study how disease might affect the brain!



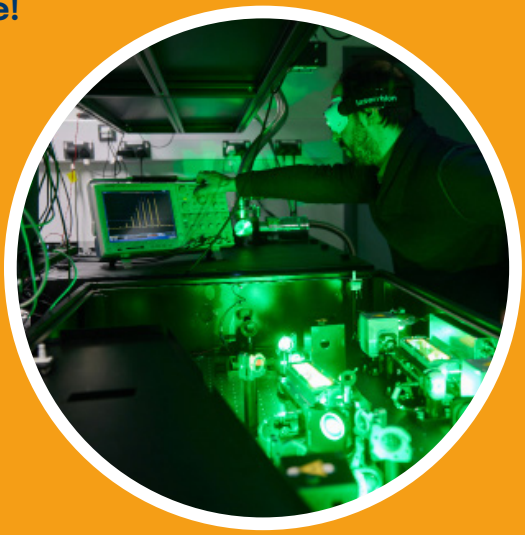
Ultra

The leaves turning from green to brown tells us autumn is here - but it also tells us something's changed in the chemistry inside...

Colour helps us learn about the world around us, and using different colours of light can tell us brand new things about objects. Infrared light, for instance, can illuminate carbon dioxide in our atmosphere, while ultraviolet light can show us unseen markings on plants that attract insects.

Ultra is incredibly flexible!

- It can use a huge variety of colours from ultraviolet to infrared.
- It can use its range to see how fast processes lead to slower ones.
- It uses infrared light to see how molecules vibrate, bond, and break apart.



Ultra can take 100,000 spectra every second! It uses rapid flashes of light to record information from molecules in chemical processes.

ULTRA NEWS

Harwell, Oxfordshire June, 2024.

LASER VISION

Scientists at Ultra found a way to decode what is inside a bottle without looking! If we fire a laser at the object, it shows us a distinct light pattern that tells us what it's made of. This is now used in Cobalt scanning machines at some UK airports!

GET ENERGISED

From developing solar cells to making more sustainable batteries, Ultra's study of materials is helping us to understand how we can make and store cleaner energy. This is important research for our future!

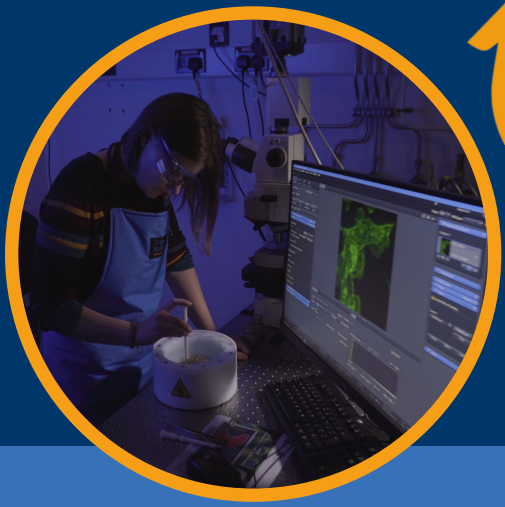
MINI MECHANICS

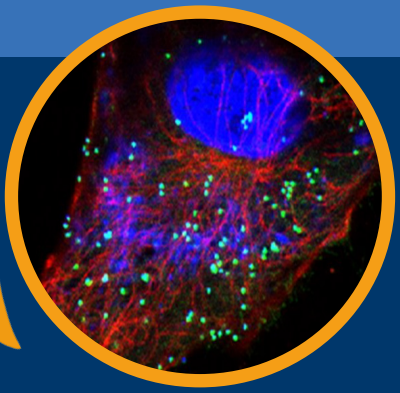
Ultra's light allows researchers to watch as proteins in the body work like tiny machines to keep us healthy. They can also see how medicines interact so we can make them as effective as possible!

Octopus

Microscopes, cameras, and our eyes... all of them use light to produce an image of something that interests us. We can use lasers to fuel powerful microscopes that produce highly-focused images and see objects far smaller than usual... down to individual atoms!

Octopus has many different microscopes and imaging facillities, all powered by lasers!





Each one uses its own technique to help us view a whole range of objects – check out this cell from a bird!

It's laser facilities like Octopus that help us understand why the world around us operates like it does - for example, why a chemical molecule breaks down into a new material, or how a protein works to help our body.

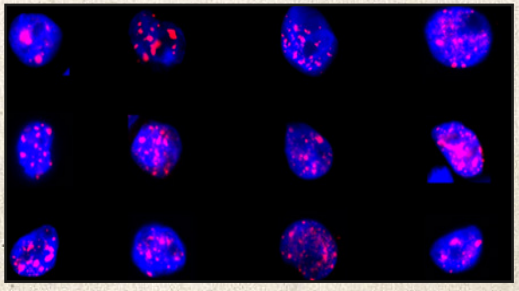
OCTOPUS NEWS

CLOUD COVER

Researchers here at Octopus recently looked at how tiny aerosol particles interact with oils and fats in the air! This is helping us understand why some molecules take so long to naturally break down, which may affect our climate.

CELL DATA

Octopus is used to look at how DNA inside cells is damaged, how this can lead to diseases such as cancers, and how the body then attempts to repair. This could give us an insight when developing new treatments.



PLANT POWER

Fluroescence microscopy can show how food is transported within plant cells and how they respond to fight infection, just like in animals!

Find the answers on the back cover!

QUIZ!

1. What is the name of the scanning machines invented at the CLF that can be found in some UK airports?
a. Copper
b. Nickel
c. Cobalt
d. Zinc

2. What type of wavelength sees heat?
a. Infrared
b. Microwaves
c. Gamma rays
d. Visible

3. Which laser can be tuned to many different colours?
a. Artemis
b. Ultra
c. Octopus

4. Can you find lasers in nature?
a. Yes
b. No

5.What laser technique is like a 'tractor beam'?
a. Spectroscopy
b. 3D imaging
c. Optical trapping
d. Fluorescent imaging

6. How thin is graphene?
a. A single layer of atoms
b. A double layer of atoms
c. A triple layer of atoms

7. What animal is the cell on pg.18 from?
a. Human
b. Mouse
c. Insect
d. Bird

8. What can we use lasers for?
a. Imaging mouse neurons
b. Learning how to make better batteries
c. Studying DNA damage
d. All of the above

Quiz Answers: 1. c, 2. a, 3. b, 4. b, 5. c, 6. a, 7. d, 8. d

UK Research and Innovation