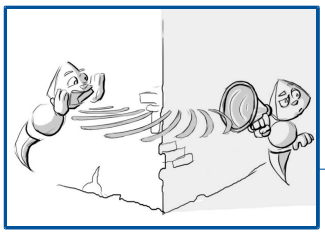


Sound waves bend around the corner of a house

Light – ruler of the nanoworld

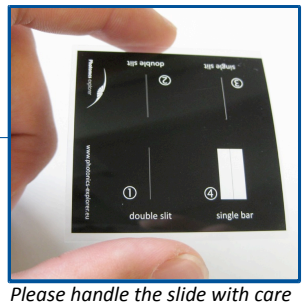
Have you ever wondered why you can hear someone speaking, although she is standing around the corner of a building? Well, when the sound waves reach the corner of the building, they go from there in all directions, also behind the corner. This effect is called 'diffraction'. Now, you have probably heard that light is a wave too. So if you can hear her around a corner, why then can't you see *her?*

Actually, light waves *do* go around the corners of a house. But there is a significant difference in scale: light waves are one million times smaller than sound waves. That's why the effect is so small that you cannot see the light bending around the house (which is much larger). On the other hand, you can see the effect if you put a tiny object into a laser beam – it causes an interesting light pattern behind the object. This light pattern results from the light bending around the object, just as the sound waves bend around the house edge.

Understanding how this works allows us to take the size of very small things. We then can use light as a ruler to measure objects at micro- and nanometre scale. In the following experiments, for instance, you will use the effect of diffraction to measure the width of your own hair.

You are only allowed to do the following experiments if you follow the **laser safety rules!**

Preparation: Set up a screen at least 8 cm across, e.g. a piece of paper stuck to a folder or a box. Place the laser at a distance of a bit more than one meter and switch it on – ideally you should now see one small bright spot in the middle of screen. Switch the laser off and carefully pick up the black slide, holding only its edges. Avoid leaving any fingerprints or scratches on the slide. In the fields marked with ③ and ④ you will see a transparent line (slit) and a dark line, respectively. Both are about the same width.



Please handle the slide with care

1 Mount the slide into the laser beam so that the beam hits the middle of the transparent line in ③. The slide should be one meter away from the screen. Sketch the **light pattern** you see on the screen in the box marked ③. Then replace the transparent line with the dark line in field ④. Sketch the second light pattern you see in the box (marked with ④) below the other one. The scale may help you to make a proportional drawing.

③ *slit*

④ *bar*

2 What do you note if you compare the two patterns?

3 The **formula** to calculate the positions of the bright spots, the so-called diffraction orders, is derived in a similar way to the formula for the double slit. However, for the experiments with single slit and bar, it is easier to calculate the **positions of the minima**, that are the dark areas in the diffraction pattern:

$$\frac{\text{slit or bar width } (d)}{\text{wavelength of laser light } (\lambda)} = \frac{\text{distance between slide and screen } (b)}{\text{distance between first minima and central spot } (a)}$$

The first minima are not always easy to detect on the screen. To improve the accuracy of your measurement, it might be better to measure the distance between the two second minima to the left and right of the centre, respectively, and to divide the result by 4.

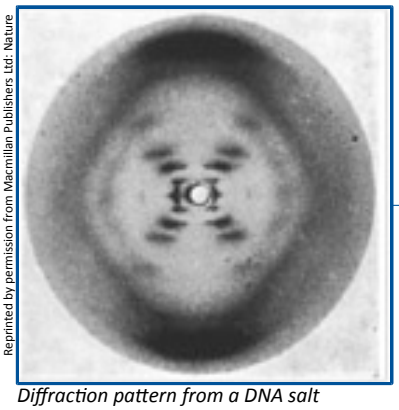
4 With your experimental setup and the formula, you can now measure tiny objects, like very thin wires or **hair**. Try it! Switch off the laser, and mount a hair on the front of the laser, either with blue tack or sticky tape, as shown in the picture. Ask your teacher for the wavelength of the laser, measure the other quantities you need and then calculate the width of your hair. What can you do to make your measurement as accurate as possible?

A hair in the laser beam

wavelength of laser light: _____

distance between hair and screen: _____

object	distance 1st minima to centre	width
my hair		



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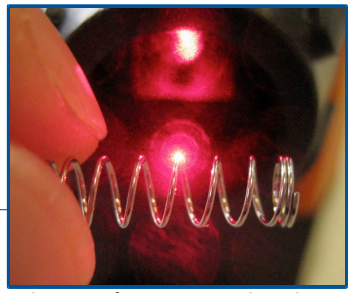
Diffraction pattern from a DNA salt

! 5 With diffraction patterns, it is also possible to learn more about the structure of tiny objects. A good example is the discovery of the double helix **structure of DNA.** DNA is the short name of a molecule in the cell core that holds the genetic information about the way living beings are built. In 1952 Rosalind Franklin recorded the diffraction pattern of DNA (as sodium salt) that you can see at the left. This photo became famous when James Watson and Francis Crick used it as proof that the molecules building our genes are structured like helices.

6 You can get an idea of how this experiment worked by holding the **spring** from a pen into the laser beam. Do not forget first to remove the hair from the laser, and please be careful with the reflections from the metallic spring. Can you see a pattern similar to that in the picture of Rosalind Franklin?



Helic spring from a pen in a laser beam

? 7 The helix of a DNA molecule is about 2.5 nm wide. That is quite a bit **smaller** than your spring, and even smaller than the wavelength of the laser light you used. What do you think Rosalind Franklin had to do to record a diffraction pattern from such a tiny structure?