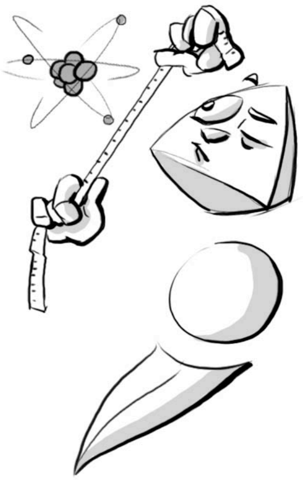
Light – ruler of the nanoworld



Diffraction not only produces interesting visual effects by generating spots on a screen, it is also a powerful tool for the study and measurement of tiny objects. Although the phenomenon has been known about for centuries, it is of special interest today. More and more technology relies on micro- and nanometer-sized particles – too small to be seen by a normal microscope. By understanding diffraction and the interference of light waves and using them smartly, not only can we peek into this microscopic world, we can even manipulate objects in it.

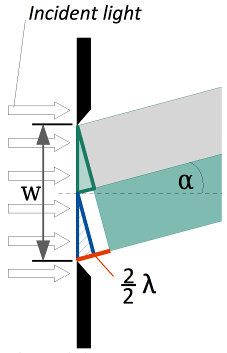
Facts to remember

- The diffraction and interference of light can be used to make very precise measurements of tiny objects on the scale of micrometers.
- The diffraction pattern can also reveal materials' three-dimensional, atomic structure.
- Two objects with complementary transmission properties (where one is transparent, the other is opaque, and vice versa) produce the same diffraction pattern. This is known as Babinet's Principle.

How it works ...

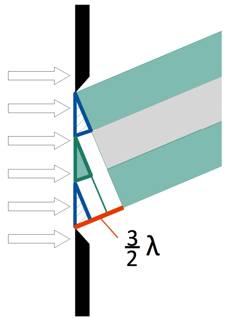
In Thomas Young's experiment with a double slit, the light that passes through one slit interfered with the light that passes through the other. But if there is only one slit – what is the light passing through it interfering with?

Actually, it just **interferes with itself**. If you compare the size of the slit to the wavelength of the laser light, you will see that the slit width is roughly 100 times larger. So you can imagine that the light at one point of the slit interferes with the light from any other point of the slit. But how can we know what the diffraction pattern for the single slit will look like?



First minimum

In the case of the single slit, it is easier to explain the dark spots first, where the diffraction pattern has a **minimum**. In the upper right-hand drawing, the light at the lower edge of the slit is just one wavelength ahead of the light at the top. If we divide this light beam into two parts, you can see that, for each point in the upper part of the beam, there is a corresponding point in the lower part of the beam, with the light being delayed by just half a wavelength. So, all the light in the upper part will interfere destructively with the light in the lower part. In this direction you can thus see the first minima in the diffraction pattern. If the light at the lower edge of the slit is 2, 3,… wavelengths ahead of the light at the upper edge, it is just the same – in these directions you will see no light on the screen.



First maximum

On the other hand, if the light at the lower edge is just 3/2 wavelengths ahead, one third of the beam will not interfere destructively with the rest and you will see a first **maximum** in the diffraction pattern. If you need to, you can calculate the diffraction angle α_m for the m^{th} minima with $m\lambda = w \sin(\alpha_m)$, where w is the width of the slit, and λ is the wavelength of the light. For the maxima, however, the formula is just a bit more complicated: $(2m + 1)\ \lambda/2 = w \sin(\alpha_m)$.

... and how it is used to save lives.

Some diseases can change the form and size of a person's red blood cells. The blood can then no longer transport enough oxygen, which may lead to the death of the patient. To recognize this problem and react early enough, doctors make use of both diffraction and Babinet's Principle: Modern medical devices compare the diffraction pattern of a small sample of red blood cells with that of holes in a plate which have the optimal round shape and size. If there is any anomaly, it can be immediately identified by a difference in the diffraction pattern.

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