Visualising invisibility

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Invisibility has been an ingredient of myths, novels and films for millennia – from Perseus versus Medusa in Greek legend to James Bond's latest car and Harry Potter's cloak. A new study published today by the Institute of Physics reveals that invisibility is closer than we think.

The paper, Notes on conformal invisibility devices, published in the *New Journal of Physics* describes the physics of several theoretical devices that could create the ultimate illusion – invisibility.

"Objects are visible because they reflect light rays" says author Dr Ulf Leonhardt at St Andrews University, Scotland. "To be invisible, an object would have to let light pass through it, like H. G. Well's Invisible Man. Alternatively light would have to bend around an object for it to be invisible. The ideas in this paper are based around devices that will bend light or radio waves around a hole inside the device. Any object placed inside the hole will become invisible. The light would flow round the hole like water around an obstacle."

The bending of light is the cause of many optical illusions, such as mirages in the desert. Light bends in the hotter air near the ground in the desert and this causes a reflection of the sky on the ground – a mirage.

Dr Leonhardt went on to say "The devices work by bending light, as in a mirage. However, a mirage involves the reflection of light which produces the shiny image that can be seen: an invisibility device bends light without producing an image. To do this, the devices must have carefully designed refractive index profiles. The paper explains the

physics and mathematics behind the devices using images rather than complex equations: it visualizes invisibility."

The refractive index is a measure of the optical length that light has to travel in a medium: the higher the refractive index, the longer the optical path is to the light ray. Light rays bend when the refractive index of the medium they are travelling through varies. According to Fermat's Principle of optical paths, light will follow the shortest optical path length. In the case of the mirage, air closer to the desert ground is hotter and has a lower refractive index than the cooler air higher up. Therefore light bends close to the desert floor in order to stay in the lower refractive index region.

Dr Leonhardt added "The next step is actually making one of these theoretical devices. There are advances being made in metamaterials that mean the first devices will probably be used for bending radar waves or the electromagnetic waves used by mobile phones. Such devices may be useful in wireless technology, for instance in protecting sensitive electronics from mobile-phone radiation in airplanes. After these have been developed, it is possible that devices that work for visible light are not too far behind."

Abstract link: www.iop.org/EJ/abstract/1367-2630/8/7/118

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