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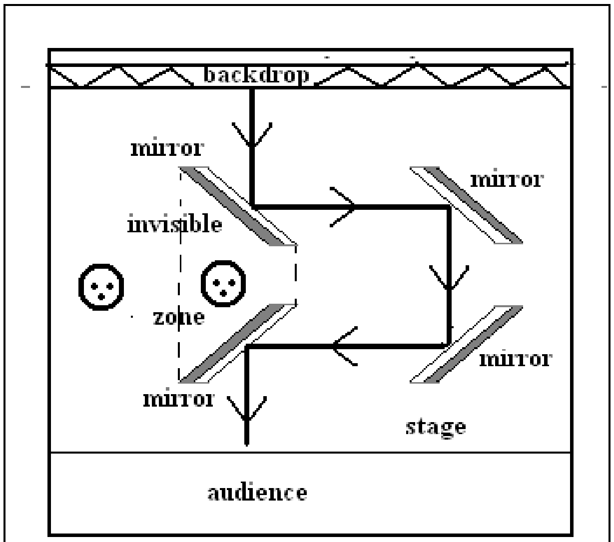
Staying out of sight

There is more than one way for things to fade from view, says, S.Ananthanrayanan.

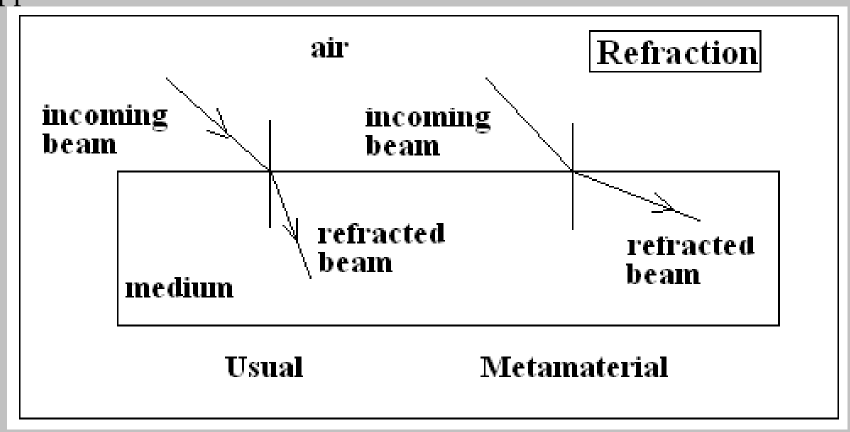
The ***cloak of darkness***, which makes its wearer invisible, is a common fairy tale motif. But it has now become reality through the use of materials that do complex things to light and make light go around an object, instead of being blocked or reflected. Moti Fridman, Alessandro Farsi, Yoshitomo Okawachi and Alexander L. Gaeta from Cornell University, USA report in the journal, ***Nature***, another method of achieving effectively the same thing - by getting light to slow down, and then rushed to catch up, during an instant, to miss an event that takes place during that instant.

One way for an object to avoid being seen is to let light just pass through. But objects in general are not transparent and would interact with light that falls on them. Even if there were a transparent coat on the object, light that falls on the coat would get bent towards the object, which would then interact, generally by reflecting the light. Persons in front of the object would then see the object and persons behind would see a shadow. But if the light falling on the transparent coat could be made to turn not towards the object, but away, then the light could be guided, through the coat, around the object, and sent on its way from the other side of the object. If this happens, then persons in front of the object would not see no reflected light and persons on the other side would see no shadow. The object would disappear!



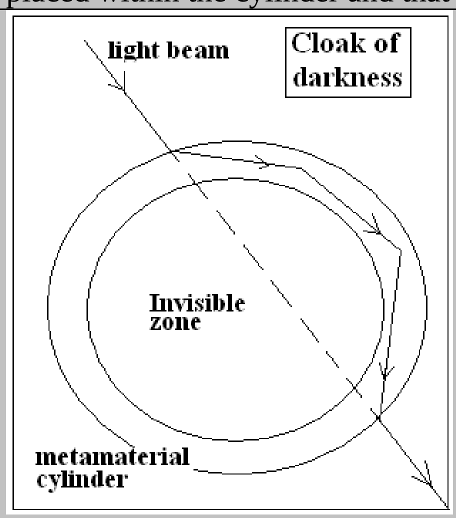
magicians do it with mirrors

The reason that light that enters a transparent medium is turned ‘inward’, or towards the direction along which it came to the medium, is the ***refraction*** of light. This is usually explained as because light travels slower in the medium than in air, and this causes a beam of light to bend inwards. But the change in direction of light is in fact concerned with the electric and magnetic properties of materials and the fact that light is a wave that consists of electrical and magnetic fluctuations. The interplay of the electric and magnetic properties of the material affect the electric and magnetic components of the light wave in such a way that for all natural materials, the direction of propagation changes within the medium, and away from the surface of the medium. In theory, the nature of electric and magnetic interactions can be such as to result in the beam bending the other way, but this does not happen for natural materials.



Metamaterials

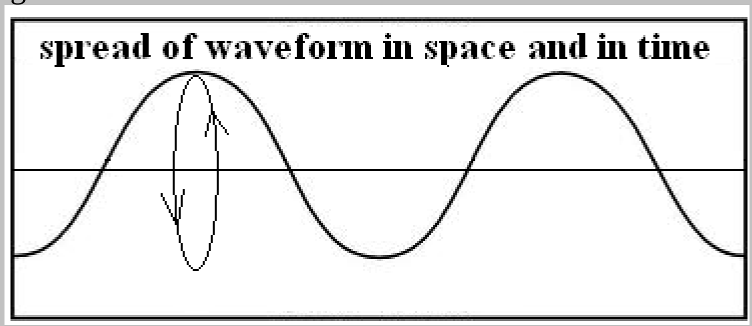
But artificial materials can be created which do affect light in this way. The world of ***metamaterials*** consists of compositions of materials designed to have more properties than the components. The components are microscopic in form and the structure has features that are of the dimensions of or lesser than the wavelength of light. Materials like this can have electric and magnetic properties, known as ***susceptibility*** and ***permeability***, which allow for light entering the material to bend in the opposite way. A cylinder made of such material can be designed so that light falling on one side turns along the surface of the cylinder and goes all the way round, till it is allowed to escape and continue along it original path. The beam of light would then be quite unaffected by an object that is placed within the cylinder and that object, in effect, would be invisible!



Metamaterial invisible cloaks have been implemented only for specific bands of light in the microwave region and are far from perfect. The dimensions of the objects that can be cloaked are also very small. Recent reports are of cloaks made not of bulk metametial but an ‘ultrathin’ cloak, which works by creating waves which interfere with reflected waves and prevent reflection from emerging from the object. This cloak is able to conceal larger objects, again in the microwave region. Prof John Pendry of the Imperial College, London, who pioneered the work, however, cautions that a practical invisible cloak is still a far cry. It works with objects a few centimeters across but it is not a cloak you can drape on anything, he says.

Hole in time.

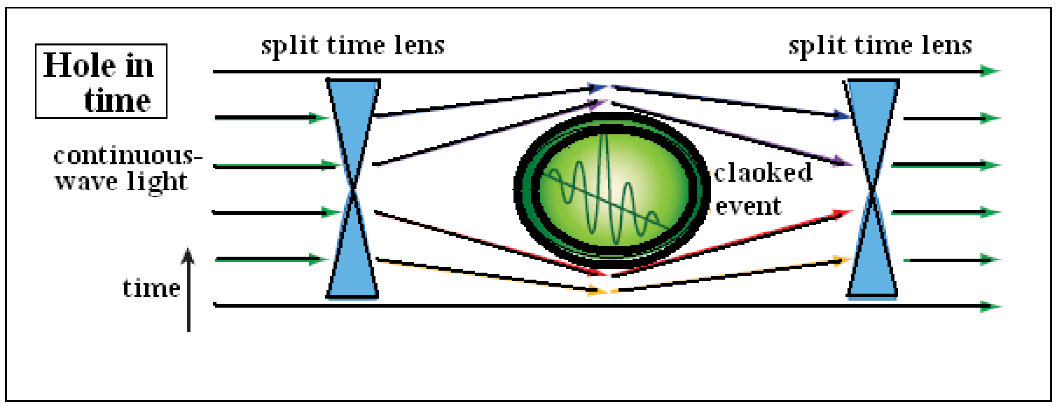
These methods of turning a light beam to flow around an abject are using ways of dealing with spatial properties of light waves, to create, as it were, a hole in space, where an object can hide without being seen. But the mathematical equations that deal with the way electromagnetic waves behave allow nearly the same manipulation that is possible with space to be carried out with the time dimension. A wave on the water, for instance, has the form of a snake, to show the height of the water along a line in space, at any moment. But if we consider a single point in on the surface of the water, the water level that point also rises and falls, as time goes on, in the same way as it does along a line on the surface, at a given instant.



Using this parallel, another approach to invisibility is to slow light down for an instant, and then to speed it up again, to catch up with the time that has passed, so that there is a gap in the time for which the wave has been there. An event that occurred during that instant would then have avoided being detected by the light wave. The method makes use of the idea of a ‘time lens’, which could expand and magnify a short pulse of time, to become detectable, just like a glass lens can magnify fine print. This concept was first developed to help detect electrical pulses that were very close together, in time.

The way it works is that an external light wave, with a varying frequency, is added to the first light waveform. The external wave creates combined waves with the original wave. If there are two closely placed peaks in the original wave, there are two, different, combined frequencies created, as the external wave interacts with each peak at a different time. These waves of different frequencies can then be separated and the two peaks get prised apart.

The same idea is implemented with a light wave, again in the microwave region. A pair of time lenses splits the light wave into a higher and a lower frequency component. Now, a prism is able to split light into the colours of the rainbow because different frequencies travel at different speeds and hence bend in different ways in the prism. In the same way, the light beam that is passed through the pair of time lenses splits into a ‘fast’ component and a ‘slow’ component and they separate. The two components then reach another, complementary pair of time lenses, which reverse the speed changes, to restore the light wave to the way it was at the start. But in the gap between the two sets of time lenses, there was a part of the beam that was ‘fast’ and a part that was ‘slow’, with a gap in between. If an event that affects the light beam occurs in the ‘time gap’, it would have no effect on the beam.



Art works in museums are sometimes protected by laser beams. If a burglar could create a time gap, he could slip in undetected. This was tried out by the Cornel University team, using three different lasers for the main beam, the varying frequency addition and the ‘event’. The ‘event’ beam became undetectable every time the lime lens was switched on, but the time gap they created was very brief, just 40 trillionths of a second,. That burglar would have to be quick!