Invisibility Cloaks: Fact or Faux?

Peering into the Invisible

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Introduction - What is Invisibility?

In optics, invisibility is defined as the state in which an object does not interact with electromagnetic radiation. This means that light that hits it is not refracted, reflected, absorbed or scattered. You can imagine invisibility by using a simple analogy with a teabag and a river. If a teabag is dropped into a river, others downstream can sense its presence through the changed taste and colour of the water. However, if the water could be diverted around the teabag, it would be considered “invisible” to anyone standing downstream.

Utilising Mirrors to Conjure the Illusion of Invisibility

The law of reflection states that when a light ray bounces off a surface, the angle of incidence equals the angle of reflection, relative to the surface normal. Using this rule, and the fact that light travels in straight lines, scientists have created an invisibility cloak that uses mirrors to reflect light around a cloaked area, as shown in Figure 1. The object is hidden beneath two parabolic mirrors. The first mirror focuses the incoming light to a point which gets reflected back onto the second mirror which expands the light rays back onto their original paths.

Metamaterials in Invisibility: A Trailblazing Discovery

Using metamaterials is currently the most promising path to achieving invisibility. Metamaterials are human-made materials designed to have unique optical properties that can’t be found in nature. Refraction is the result of the interaction of the electromagnetic light wave with the medium in which the light travels. In natural materials, it is primarily the electric field of the light which causes the electrons to oscillate and reradiate a new wave. However, in metamaterials, tiny sub-wavelength repeating units such as split ring resonators (Figure 3) act like miniature capacitors and coils that respond to both the electric *and* magnetic fields of the electromagnetic wave. They reradiate a wave which has the properties of light that has experienced a negative refractive index (Figure 2). This allows light rays to bend around the object and exit on the opposite side on its original trajectory. As shown in Figure 4, the metamaterial cloak can conceal an object located in its hollow centre.

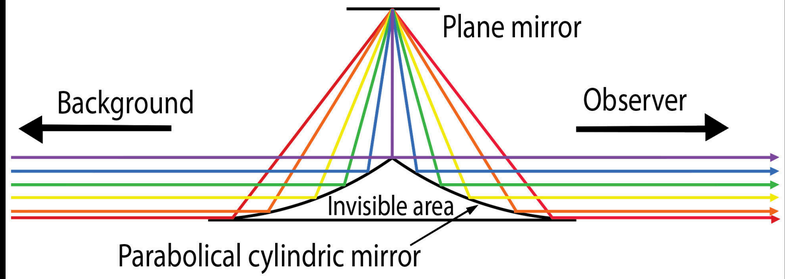


Figure 1: Invisibility cloak using the law of reflection

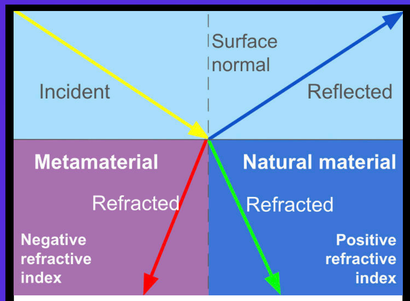


Figure 2: Positive and negative refraction

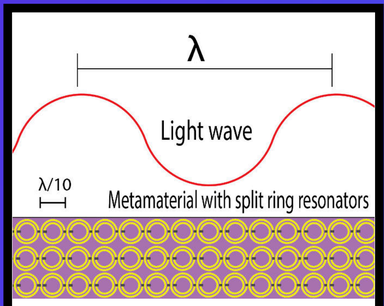


Figure 3: Metamaterial

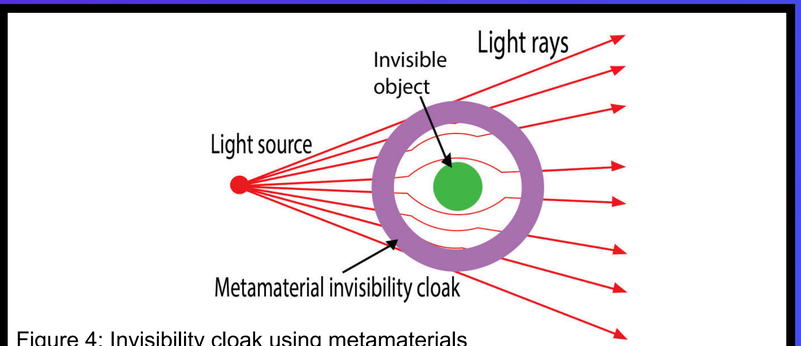


Figure 4: Invisibility cloak using metamaterials

Conclusion: Current Drawbacks and the Future of Invisibility Cloaks

Present invisibility methods are not yet ready for real-world applications. The limitation of mirror based devices is that they only work for one viewing angle. Metamaterials are limited because their atypical refraction is highly wavelength dependent, meaning that invisibility cannot yet be achieved under normal lighting conditions because the metamaterial can only be designed for one particular colour. A final challenge that scientists face is scaling up the invisibility cloaks that have been only tested at miniscule scales. When metamaterials are scaled up to cloak an object as large as a person or a car, imperfections are guaranteed, resulting in a loss of light which will be perceived as a shadow behind the object. Invisibility research could have applications that are not just limited to optics because the concepts work for all wave phenomena, including sound waves (submarines could be rendered undetectable by steering sonar waves around them), or seismic waves (earthquake-proof buildings could use metamaterials to divert incoming vibrations).

Bibliography and Acknowledgements

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