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Optical materials

Cast no shadows

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How to weave a cloak that makes you invisible

IN NORSE mythology, a magic cloak granted invisibility to Sigurd, a demi-god and skilled warrior with superhuman strength. Millennia later, a similar garment bestowed invisibility on Harry Potter, a schoolboy wizard. In the mortal (or Muggle) realm, engineers have for years tried with varying degrees of success to build such a device. This week a team of physicists and materials scientists announced it had devised a pattern for a potentially perfect invisibility cloak.

Light is an electromagnetic wave, with a longer wavelength than X-rays and ultraviolet, and a shorter wavelength than infra-red, microwaves and radio waves. All these electromagnetic waves are governed by four mathematical expressions established almost 150 years ago by James Clerk Maxwell. These equations represent one of the most elegant and concise ways to state the behaviour of electric and magnetic fields and how they interact with matter. However, because they are so concise, they also embody a high level of mathematical sophistication.

The team—Sir John Pendry of Imperial College London with David Schurig and David Smith of Duke University in North Carolina—used the equations to devise a way to cloak an object with a material that would deflect the rays that would have struck it, guide them around it and return them to their original trajectory. Maxwell's equations conserve certain properties—the magnetic field intensity, the electric displacement field and the Poynting vector that describes the electric flux of an electromagnetic field. These properties remain the same when others are altered. The team showed how these fields could be manipulated to flow around objects like a fluid, returning undisturbed to their original paths. The findings were published online this week by *Science*.

The trick is to use metamaterials: materials that owe their characteristics to features of their structure that are smaller than the wavelength of the electromagnetic radiation. For light, this is on the scale of tens of thousandths of a millimetre. Metamaterials can and have been designed and made to possess certain properties, even counter-intuitive ones. Using metamaterials means the scheme should work for all objects, regardless of their shape. Moreover, unlike other proposed invisibility cloaks, it does not require knowledge of what is behind the wearer, nor are crude projections involved.

So far, so good: the theory is in place. Sadly, the implementation lags behind. Moreover, there are several other difficulties that may prevent a device conferring total invisibility from being built. The first is that the plan described by Sir John and his colleagues works only for a small range of wavelengths. A surgeon wearing metamaterial gloves tuned to make his hands invisible might benefit from being able to see exactly where the scalpel was cutting. However, an invisibility cloak designed to hide something from people who were looking for it would not work. An aeroplane shrouded in such kit might be invisible to the human eye but it would be picked up readily by radar, which operates at radio wavelengths.

Even if it ultimately proved possible to make an aeroplane completely invisible at all wavelengths, there would be a further problem. According to the laws of physics, an invisible person would necessarily be blind. In order to see light, the eye must absorb it, but in order for a person to be invisible, the body must not absorb any light. Thus, a spy plane could not be completely invisible if it were to be used for espionage or, indeed, flown at all, since its pilots would need to know its position relative to the ground.