CRACKING THE INVISIBILITY CODE

PULLING OFF A DISAPPEARING act could soon become a reality as the world awaits a defining moment.

BY **ROHIT BASU**

Remember Dr. Sebastian Caine, a brilliant but egotistical scientist in *Hollow Man*, a Hollywood blockbuster that captured global imagination in 2000? Dr. Caine, commissioned by the U.S. military, discovers a serum for invisibility to aid and abet Pentagon's war games. Hell-bent on achieving the ultimate breakthrough, he pushes his team of researchers to use him as a subject for the experiment. The test turns out to be a success. However, the formula affects not only his external physical nature, but also morphs the internal personality, triggering a series of cataclysmic events.

The reel world has often been inspired by the real. Scientists across the globe are on a quest to crack the invisibility code. But unlike Dr. Caine in the multi-million grosser film, success in the lab has not been so spectacular. Yet, pulling off a disappearing act may soon cease to be a mere phrase as the world awaits the defining moment.

Professor Ulf Leonhardt, who is associated with the University of St Andrews, UK, and the National University of Singapore, has been at the forefront of this cutting-edge research. Ably supported by Tomas Tyc, an Associate Professor at the Masaryk University in the Czech Republic, the duo has worked on the empirical rules of making things invisible. Cloaking devices, a form of advanced stealth technology, is the medium of choice. Interestingly, popular culture, too, has been inspired by similar technology. *Star Trek*, the path-breaking TV series of the 1980s, had depicted in great detail how to render spacecraft invisible. The far-out concept demands out-of-the-ordinary devices and only works in certain colour schemes.

A look back into the past underlines mankind's fascination with the concept of invisibility. It has been the ingredient of myriad myths, novels and films: from the slugfest between Greek legends Perseus and Medusa to science fiction writer H.G. Wells' eponymous tale of the Invisible Man and J.K. Rowling's 21st century cult-fiction hero Harry Potter.

Be that as it may in the realm of popular culture, invisibility has been the fountainhead of several research initiatives in recent times.

Ulf Leonhardt and the group led by Sir John Pendry, a theoretical physicist associated with Cambridge University, had come up with the theoretical concept of invisibility devices, which was followed by a demonstration of the first practical 'Invisibility Cloak'.

Ulf took to geometry while teaching Albert Einstein's Theory of General Relativity in Ulm, Germany, about a decade ago. Incidentally, Einstein, too, was born in Ulm. In retrospect, Ulf didn't imbibe textbook knowledge of general relativity, but came to terms with the fascinating theory through lecture demonstrations. He tried to co-relate between general relativity and his field of research, quantum optics. One thing led to the other, till he stumbled upon the fascinating world of artificial black holes, invisibility and quantum forces.

Perhaps the defining moment was the summer of 2002 when he attended a three-week programme at the Kavli Institute for Theoretical Physics in Santa Barbara. It was his first brush with meta-materials. "Negative refraction was in vogue seven years ago. It became clear to me that invisibility will be the next big thing. The last missing ingredient in my research fell in place fortuitously during a chat with my travel companion on a long flight to Mexico three years ago. However, I have had my share of difficulties in publishing my first paper. Invisibility has never been a mainstream subject," reminisces Ulf.

He claims that a cloaking device, as the name suggests, will make everything invisible, including humans. Insurmountable odds aside, Ulf and Tomas Tyc demonstrated in a paper in *Science Express* that invisibility isn't a figment of imagination and stuffs that science fictions are made of.

The breakthrough can find many takers, especially in military applications. The defence strategists can add a new

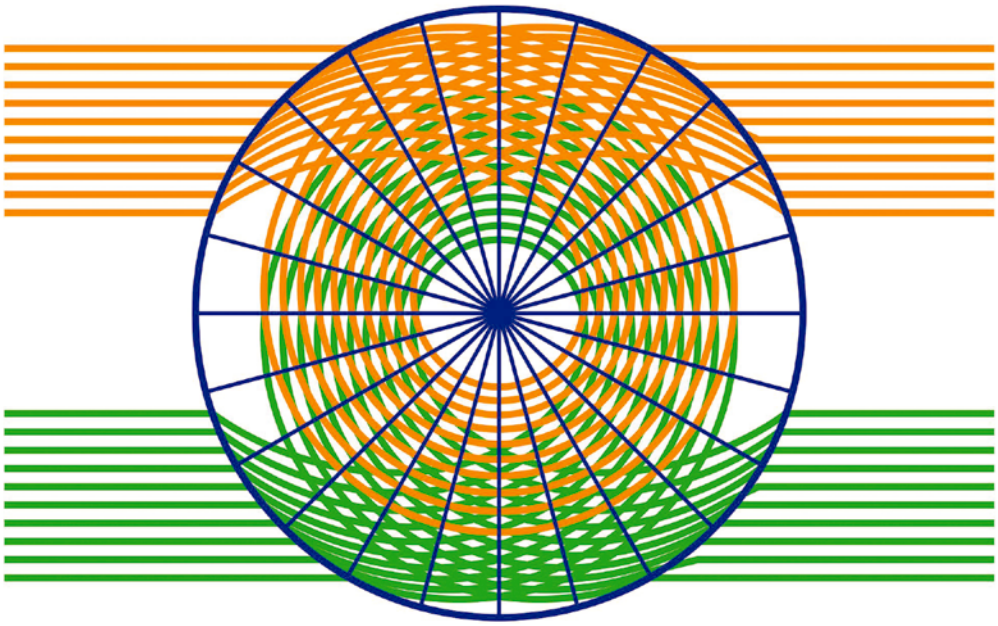
PHOTO: PHOTO12

Fictional reality: A scene from the 1958 TV series 'Invisible Man'

dimension to war games by making both objects and people invisible. A naked eye can easily see objects since they absorb and spread the light that shines on them, reflecting a part back to it. The invisible cover features the meta-materials, which can redirect radar, light or other waves that strike the object. Meta-materials are a happy blend of metal and circuit board materials, including ceramic, Teflon and fibre glass. These materials are developed to curve visible light in a special way.

Researchers aim to use these materials to eliminate the possibility of reflections or shadows. However, the technology is markedly different from stealth. The latter cannot make a plane invisible, but makes it difficult to track.

Concurs Ulf: "It can have military applications. For example, the work of John Pendry and David Smith has been partly financed by the CIA. The defence is interested in such research." Professor Juan Antonio Morente Chiquero, who teaches applied physics and electromagnetism at the University of Granada, Spain, however, joins issue with Ulf. "Loosely speaking, everything has a military application. For instance, rice is an integral part of a defence set-up because soldiers eat it," he says.



Optical magic: Transformation optics makes a real difference. The 'Chakra' moves on to make hitherto impossible optical devices possible.

Morente and his colleagues are working overtime on Mission Invisibility. They have come up with a numerical technique, Transmission Line Matrix (TLM) modelling method, which can hide or make an object invisible at a certain frequency inside an electro-magnetic simulator. Scientists claim such studies are germane to invisibility — both for radars and human eye.

"The growing interest in electro-magnetic invisibility can be attributed to the availability of hi-end computers. We developed a new condensed TLM node, which can make certain objects invisible, thanks to the latest software," claims Morente.

The future is pregnant with several path-breaking possibilities.

"Soon we will watch a film that shows an illuminated body disappearing when it is lit up by another colour. The research is related to numerical or computational simulation of physical properties that reinforce our theory," he adds.

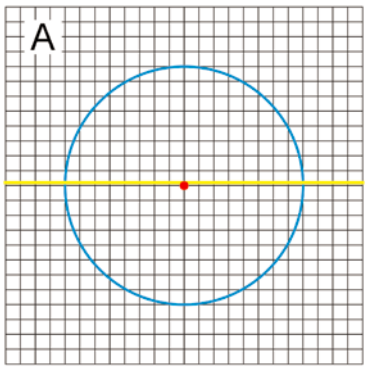
The heightened interest in meta-materials with negative refractive index has been prompted by a host of promising optical and microwave applications. Often, the electro-magnetic problems cannot be analytically derivable. Consequently, the TLM method is considered a viable option since it encourages numercial modelling.

According to Morente, the interest in invisible cloaks is fuelled by powerful computational resources, which allow numerical studies of such a phenomenon aided by state-of-the-art software.

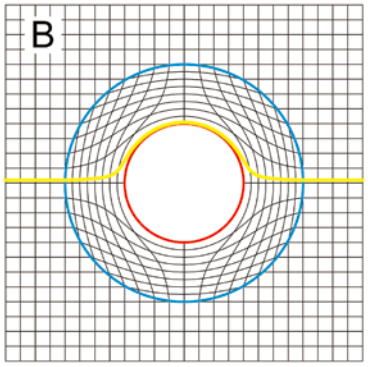
Morente and his colleagues have developed a new condensed TLM node to use meta-materials in two-dimensional situations. However, the theory also puts forth what cannot be achieved despite the software applications.

Initially, John Pendry and his co-researchers had concluded that it was possible to exclude all fields from a certain region without causing any disturbance to the vicinity. The elaborate process involves surrounding the object (that needs to be made invisible) by an anisotropic material, whose permissibility and permeability are directly obtained from coordinate transformation. This theory of invisible cloaking has been propounded by many studies. Each, however, adopts a different approach.

Scientists from the University of California, Berkeley, claim they have come very close to developing a cloak that can make both people and objects invisible. A demonstration, too, has been conducted to drive home their point.



Blink of an eye: Light passes through a point in infinitely short time



Seeing is believing: The device creates the illusion that light propagates through empty flat space

The cloak is a creation of synthetically-engineered materials, which can change the direction of light around three-dimensional objects.

Earlier, a similar method was applied only to two-dimensional objects. The use of three-dimensional materials can reverse the natural direction of visible and near-infra-red light. This finding can form the basis of nano-circuits for hi-end computers that are an integral part of higher resolution optical imaging.

Meta-materials hold the key in the field of electro-magnetism. They consist of man-made structures that are smaller than the wavelength??. They act like artificial atoms or electro-magnetic resonators. Usually, meta-materials for microwaves are made of circuit boards, as in copper structures on plastic. Optical meta-materials are also made of metals, but they require much finer structures. For example, microscopic gold wires are assembled by using the tools of nano-technology. Credit goes to the ancient Romans for inventing the meta-material. Ruby glass was the Romans' concept of a meta-material.

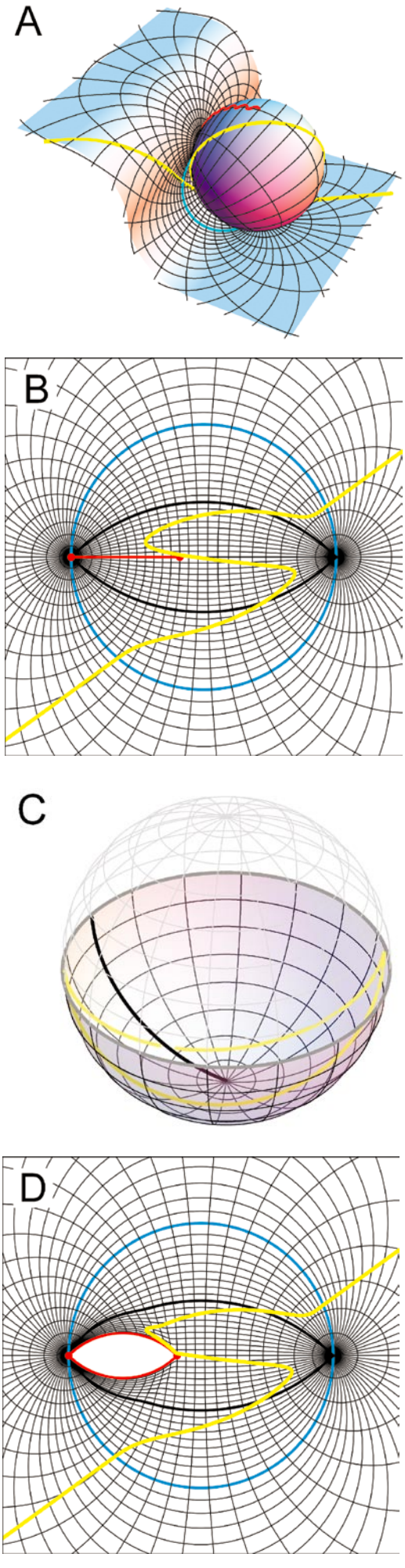
Ulf professes much simpler technical solutions for invisibility devices. "Perhaps liquid crystals will suffice once there are further improvements in the design element," he says. Researchers seem obsessed with meta-materials since they possess the rare quality to create a structure with a negative refractive index. In fact, this property hasn't been found in any other natural material. All optical materials such as glass or water boast of permissibility and permeability. A material that has either negative permissibility or permeability is found to be opaque to electro-magnetic radiation.

Visible light is the narrow band of electromagnetic radiation. It has wavelengths ranging from 400 nanometres (violet and purple light) to 700 nanometres (deep red light). However, infrared light wavelengths are shorter. They measure between 750 nanometres and one millimetre.

Natural meta-materials have a positive refractive index, which is a measure of how much electromagnetic waves are bent when moving from one medium to another. Here is an example of a medium that has a positive refractive index: The submerged part of a pole after being inserted into water will appear as if it is bent towards the surface of the liquid. If water were to exhibit negative refraction, the submerged portion of the pole would instead seem to jut out from its surface. Another classic example: A fish swimming underwater will appear to be moving in the air above the water's surface. This will hold true only if the refractive index of water was negative.

Science fiction has often conjured up the fantastic to fire popular imagination. Who can forget H.G. Wells' *The Invisible Man*, where a series of chemical reactions render a human being to pull off a disappearing act? However, the process of invisibility wasn't etched out in detail and much was left to our imagination. Bio-chemistry, as Wells suggested, had altered the invisible man's molecules to facilitate the passage of inert light.

But that's far removed from reality. The complex molecules that



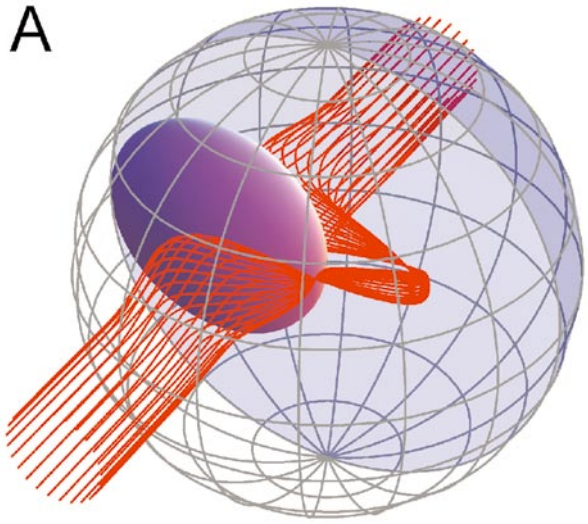
Light in motion: (From top) Light propagates through the surface of a sphere; The interior of the cloaking device has been expanded to make space for the grid of the sphere; Making the northern hemisphere invisible and creating illusion; Light never crosses to create a hidden space

PHOTO: STEPHEN/SONY PICS IMAGEWORKS VAU/ THE PICTURE DESK

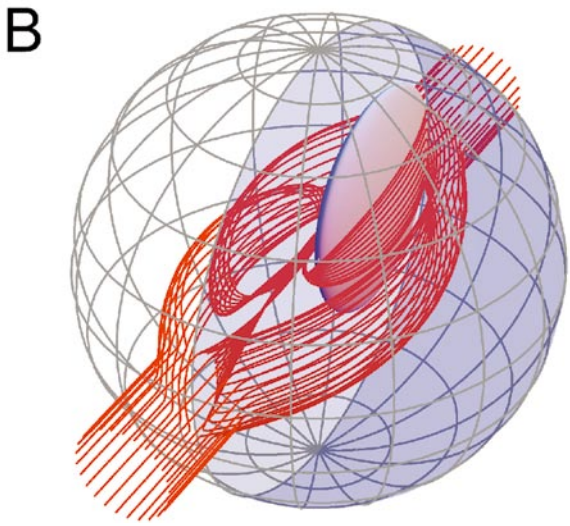
Playing with science: A still from the movie *Hollow Man* (2000), in which a group of scientists discover a serum to make people invisible, but their test subject turns into an insane killer who starts stalking them

PHOTO: PHOTO12

Novel concept: A still from *Alien Vs. Predator (2004)*, a science fiction adaptation of a crossover franchise between the titular extraterrestrials from the *Alien* and *Predator* series. The Predator (above left) can make himself invisible.



Curved vision: Light rays are bent around the invisible region



Hide and seek: Light wrapped around the invisible interior

make up humans absorb and scatter light. These interactions are often tied to other important biological functions that will probably stop working if one tries to tinker too much with the molecules.

Normally light travels in a straight path. According to Fermat's Principle, here's why light travels in a straight line: it is the shortest distance between two points. However, Einstein's Theory of General Relativity has conclusively proved that the shortest distance between two points can become a curve instead of a straight line. The trajectory of light that passes near massive objects, like the sun or black holes, is actually bent, resulting in mirage-like optical effects.

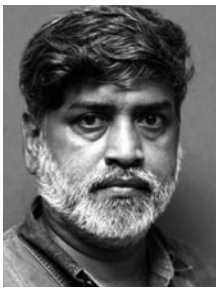
According to Ulf, the bending of light in the media is the cause of many optical illusions. A mirage in the desert and light rays from the sky — bent above the hot sand, where the air is thin and the refractive index is low — are a case in point.

Perhaps the most realistic portrayal of invisibility was in the Hollywood hit *Predator.* The blockbuster starring Arnold Schwarzenegger depicted an alien complete with a cloaking device, enabling it to disappear with ease. When cloaked, the predator was mostly transparent. But there was a discernible distortion of the transmitted light that vaguely outlined the shape of the predator. Hence, it was difficult to perceive the existence of the alien unless one kept a tab on its mobility. In hindsight, imperfect cloaking did a reasonably good job on celluloid.

Invisibility is an arduous feat, especially one that involves intricacies. Sound is the essence to cloaking. It may be fabricated by generous use of artificial materials, which have been introduced over the past several years. But there are seemingly unavoidable limitations as far as the medium is concerned.

Perhaps wireless technology has the answer to perfecting the cloaking devices act. The cutting-edge technology is manifested in latest and hi-tech models of cellular phones, which boast of blue-tooth and attendant electro-magnetic microwave devices. Microwaves have much longer wavelengths than visible light, raising hopes of a technological breakthrough in the near future.

Ulf's take on the theory is in consonance with the coming of age of wireless technology. "Though I'm not an expert on it, I think the concept can be applied to a greater effect to further the experiments," he says optimistically.



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