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Cloaking and Quantum Stealth: The Science Behind Invisibility

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ABSTRACT

Invisibility has always been a field of human interest, which was never possible in the maximum of the physicists' eyes. But the old ideas are fading away as Quantum Stealth is coming into existence as a new opportunity for cloaking. The technology is supposed to be used in military warfare and defence scenarios in Canada, especially satisfying the purpose of camouflage.

Keywords: Quantum stealth, Invisibility, Cloaking, Camouflage, Dominant scattering cancellation.

INTRODUCTION

Invisibility has been a subject of human fantasy for several hundred years. Modern scientists have discovered and developed many approaches to invisibility, each of which is called–cloaking.

What is cloaking

Cloaking means to hide or cover something. The idea of cloaking in terms of invisibility is to hide a person or an object from an observer with the help of a sheet of a cover-like thing.

Now, let's talk about Quantum Stealth

What is Quantum Stealth

Quantum Stealth is an artificial material that can turn an object into totally invisible by bending the light around the target object. It shall introduce a revolution in the field of international defence mechanisms. It is often named as "Invisibility Cloak"[1].

Guy Cramer, CEO & President of Hyper Stealth Biotechnology Corp. has invented the technology of Quantum Stealth and he is close to fully incorporating the idea into practice.

Literature Review

We've previously discussed what cloaking is. Now we'll see how cloaking is done in various ways and invisibility is achieved.

Methods of Cloaking

We will now discuss different approaches to cloaking.

Transformation-Based Cloaking

Transformation Electrodynamics

Transformation-based cloaking is based on the theory of transformation electrodynamics in which electromagnetic energy flow is used for a transformation that extends the space coordinates as Fig. 1 where the ray of light is passing through an even material. The direction of this ray can be changed or it can be bent by constricting the Cartesian space. This very similar thing was stated by Fermat in his principle. Since Maxwell's Equations are unchanged in transformations so the transmission of the untransformed coordinate system can be repeated with the distribution of tensors-permittivity (ε) and permeability (μ). The geometrical distortion leads to a practical way of creating transformation on coordinate system in physical space. Metamaterials may therefore be used to imitate the transformation leading the light to follow curved coordinates, at least in principle.

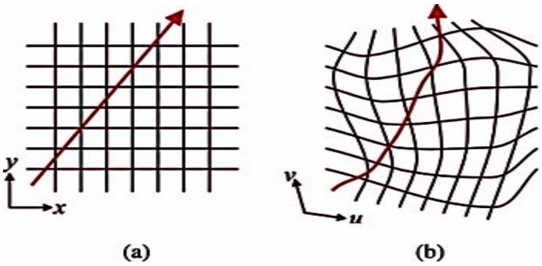

Fig. 1. Light manipulation possibilities offered by transformation optics. © 2006 AAAS.[3]

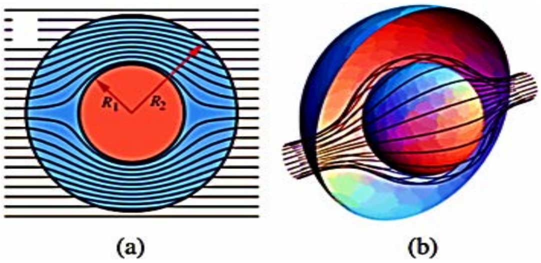

Fig. 2. Operation principle of transformation-based spherical cloaks. ©2006 AAAS.[3]

Spherical Transformation Cloak

For spherical cloaks, we can use the transformation-independent method. Scientists use a non-ideal discrete model which helps in optimizing the total scattering cross-section of generating function. Notably, a bell-shaped cloak can be used because in it the parameters can be changed accordingly. This type of invisibility lasts for a long time even in a highly discretized model.[2]

Non-Euclidean Transformation Cloak

There are some transformations that can be obtained on a spherical surface instead of a plane. Non-Euclidian transformation is such a kind. In this type of expansion infinite expansion and singularities can be avoided. By this concept, we can be benefitted due to avoidance of superluminal propagation. All angle broadband cloaking in the visible makes this concept extremely promising.[2]

Carpet Cloaking

Li and Pendry proposed the concept of carpet cloaking[4]. In this type of transformation quasi-conformal mapping is used. It reduces anisotropy in a two-dimensional system. The scientists show that due to the application of the optimization procedure, we can achieve transformation media with a dielectric material. It also provides a few reasonable values of permittivity. In visible frequencies, such types of transformations may be executed.

This concept can be used to make a mirror having a bump that will appear totally flat while covered by a carpet cloak. The graded-index profile of the cloak makes the mirror look flat as it is surrounded by a 'perfect electric conductor' (PEC). A cloak resists the scattering of the incident beams on the bump; thus, it helps to make it invisible.[2]

But this quasi-conformed mapping can work only on 2D geometry. Surely, in 3D the bump won't look flat. The only way to partially set this drawback to prefer the photorealistic images of the object in a three-dimensional scenario in carpet cloaking can be generated by ray-tracing algorithms. In most broadband, this technique is extensively used to explore the performance. In three-dimensional, Carpet Cloaking image distortions are quite obvious. For getting the flat bump using a cloak, a mirror reflection operator is required, which is also a drawback of this type of transformation. The reflected ray suffers lateral shift which is equal to the height of the bump. The reason is in this type of cloaking anisotropy is being reduced to a large extent. So, this type of isotropic cloak can't be used, rather second ground plane could have been a better option.

In this way, the observer can detect the presence of some material under the cloak but that won't be visible. For getting quasi-confirmed mapping in 3D we need anisotropy in our cloak.[2]

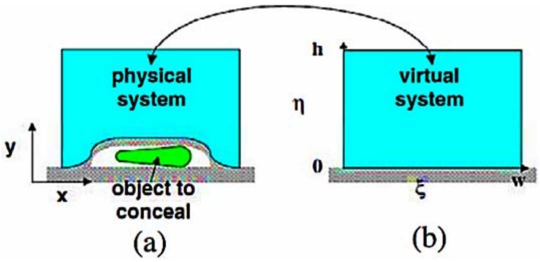

Fig. 3(a), 3(b). Operation principle of a carpet cloak. © 2008 APS.[4]

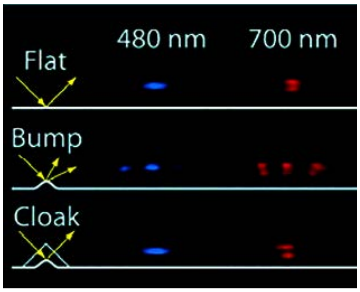

Fig. 4. Experimental validation for carpet cloaking in the visible spectrum. © 2011 ACS.[10]

The experiment cannot be extended directly to optical frequencies as the metal elements used will consume some energy. Several successful studies and experimentation have also reported in favour of validating broadband carpet invisibility at infrared frequencies to observe 2D invisibility[5-7]. The carpet cloak is designed for 2D bumps in addition, but at infrared frequencies, it is characterized by 3D and has good reduction of scattering for up to 60 degrees of wide out-of-plane viewing angles[8]. The ground plane cloak has also been constructed and characterized for full 3D axisymmetric impacts at microwave frequencies[9]. Finally, the carpet cloak was experimentally validated at visible region frequencies in the wideband range[10]. Fig. 8 shows the experimental results in [10] and confirms the invisibility of the projections in the mirror under extreme blue and red-light conditions. It is also worth noting that the probability of using smart materials to get invisible carpets is very high. These materials can naturally obtain the correct gradient-index distribution from elastic deformation caused by bumps[11]. To avoid the problem of lateral slippage, it is necessary to keep the weak anisotropy preserved in the carpet cape[12]. Therefore, perfect carpeting still requires anisotropy. Researchers, in 2009, have succeeded in simulating anisotropy using conical waveguides[13]. This indeed leads to observing the broadband invisibility based on optical frequency coordinate transform. It is worth noting that the invisible field is twice as large as the wavelength of light.

However, this stealth strategy can only be applied to waveguides of certain shapes. Another possible way is modifying the carpet invisibility transformation to achieve a variant of carpet invisibility, which can be directly accomplished using natural materials, which are anisotropic but will not be affected by the lateral slip problem, so that carpet concealment can be used to hide the larger area. Topic[14,15]. This enhanced carpet cape uses birefringent natural dielectric crystals, visible light calcite[16,17], and terahertz sapphire[18] for affine conversion. Using this method, it is possible to perform 2D carpet masking of macroscopic objects at a wide range of angles of incidence without lateral shift, but this is only suitable for one type of polarized light.

Other suggestions include constructing standalone variants of the carpet cape that have no requirement of a ground plane. Those extraordinary types of carpet covers are invisible in an exceedingly single route or in a couple of directions[19-21] and can be applied in microwaves[20,21] within basic terms herbal birefringent dielectric crystals[19] or by way of other means. The compromise right here is to sacrifice invisibility from all angles to reap a few simplicities in design. Notably, some other suggestions go further in simplification by seeking unidirectional or omnidirectional obfuscation and also eliminating the need to recover the external field phase[22,23]. The answer to this very problem is trivial: it is possible to be accomplished using lenses or mirrors[23], as defined in an e-book written more than one and a half centuries ago by the means of the well-known magician R. Houdin[24]. Therefore, in particular, there is no scientific difficulty in obscuring an object in only one or numerous directions and without phase protection. On dropping of phase requirement, the actual challenge, which comes up, is to hide from all the directions, as is referenced in non-Euclidean transform hiding[25]. Alternatively, if we cancel all angle requirements for carrying out one-manner obfuscation, the real challenge to science is preserving the phase as discussed in[20].

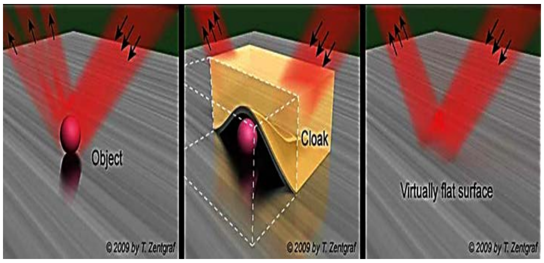

Fig. 5. Carpet Cloaking; Source: https://newscenter .lbl.gov/2009/05/01/invisibility-cloak/

Plasmonic and Mantle Cloaking

These types of cloaking deal with the dominant scattering cancellation technique.

Plasmonic Cloaking

Plasmonic covers have been shown to provide local negative polarizability with a capacity of reducing or cancelling the dominant scattering from an isolated or a cluster of objects.[2]

Mantle Cloaking

In mantle cloaking, an ultrathin isotropic surface is used, which is frequency selective. Minimising the (surface) impedance, which the mantle cloaks include, results in cancelling the dominant scattering from the object.[2]

Hybrid Methods & Miscellaneous

A recent work[26] showed some encouraging experimental results for a hybrid technique that intends to use both the dominant scattering cancellation method and transform optics. A cloak with many layers is used to make a cylindrical item invisible. By design, the cloak does not use superluminal diffusion. Some layers are employed to cancel the main scattering multipole; however, anisotropic materials are used in trying to exploit the transform technique. The cloak is mathematically developed utilizing optimization algorithms. Because the action is not resonant, it is fairly wide. However, the total observed scattering decrease is not particularly substantial.

Another method of concealing exploited the mirage phenomenon with thermally manipulated transparent carbon nanotube sheets[27]. Shielding in the diffusion regime of light propagation was accomplished in another study by using a dominating scattering cancellation approach to Fick's diffusion equation[28].

Some of the alternative cloaking techniques are:-

1. Cloaking using transmission-line networks
2. Parallel-plate cloaking
3. Anomalous resonances
4. Active cloaking

Possible applications of Cloaking: -

Acoustic waves

Acoustic waves are highly desired to be cloaked in a number of applications. For example, the invisibility of sonars.[2]

Thermal waves

There are theoretical proposals which promise to mould the heat flow, ensuring us that creating such a thermodynamic cloak is possible that a conductive object neither stays in touch with heat nor perturbs the heat flow.[2]

Quantum matter waves

If the transformation method is applied to the effective Mass-Schrodinger equation, the theoretical realization helps us to imagine furtive quantum sensors.[2]

Surface liquid waves

Shielding floating bodies from surface waves can be an application of this.[2]

Cloaking a sensor

This is related to cloaking a sensor for the sake of cancelling or reducing its scattering so that it remains undetectable by any other sensor but it still manages to receive signals.[2]

Quantum stealth: a special application

When did it all start

Hyper Stealth is a company established in 1999 and is well-known for its contribution to the worldwide arms trade. It is one of the leading suppliers of camouflage patterns and technologies to militaries globally with pattern designs of over 14,000.[1]

Guy Cramer, the President & CEO of Hyper Stealth, the creator of all those designs, is the mastermind behind the concept of "the Invisibility Cloak".

Donald L. Hings, who was the inventor of a walkie-talkie and owner of 56 other patents, was the grandfather of Cramer. Having been his grandfather's research assistant (formerly), Cramer has always had innovations budding in his core.

He started developing his own military camouflage techniques, which were based on mathematical fractals (or, feedback loops) in 2002, which brought a radical change in the camouflage industry and introduced the art of camouflage to the area of science and technology.[1]

Cramer's journey to creating Quantum Stealth was set in motion in 2011.

In October 2019[1], he made an application for four patents related to the materials that were supposed to be useful in military purposes–to hide/ conceal men and utilities such as jets, tanks etc. Quantum Stealth is still in its prototype stage.

How does Quantum Stealth work

Guy Cramer demonstrated that the efficiency of Quantum Stealth is not only limited to the visible region of light. It bends the Ultraviolet, Infrared, and Shortwave Infrared spectrum with the Thermal Spectrum, which makes it a real "Broadband Invisibility Cloak".[1]

Quantum Stealth is made up of a lenticular lens i.e., a corrugated sheet of which, every ridge is made up of a convex lens. The layering of the clear sheets is done in a way such that light can be reflected from numerous angles creating "dead spots". Light cannot pass through these spots any longer, which leaves the subject hidden behind them from viewers while the background of it remains unchanged.[1]

Fig. 6. Conceptual Visualisation of Quantum Stealth; Source: https://phys.org/news/2012-12-quantum-stealth-material-invisible.html

Where can Quantum Stealth be applied at

Cramer predicts that his invention will be used for things, such as–riot shields, parachutes, pop-up tents or camouflage nets.[1]

Still, now this technology requires a certain stand-off distance of the subject from the cloak, for which, it is right now impossible to use this as clothing.[1]

CONCLUSION

We have reviewed some of the recent studies in the field of invisibility and cloaking in this paper. The types of cloaking that we believe to be relatable to the idea of Quantum Stealth have been highlighted. We have mentioned some applications of cloaking and have chosen Quantum Stealth as a special application. We have given short information on how this new technology works as well as what it is. We hope we made sense in this review paper and it was really worth doing. We look forward to a day where invisibility will get included in man's everyday life yet with the assurance of the safety of mankind.

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Conflict of interest: Declared none

REFERENCES

1. https://globalshakers.com/quantum-stealth-an-invisibility-cloak-that-can-hide-people-buildings-and-military-jets/
2. Fleury, R.; Alù, A.; *P. I. E. R.*, **2014**, *147*, 171-202.
3. Pendry, J. B.; D. Schurig, and D. R. Smith, "Controlling electromagnetic fields," *Science*.,

2006, *312*(5781), 1780-1782.

4. Li, J. and J. B. Pendry, “Hiding under the carpet: A new strategy for cloaking,” *Phys. Rev. Lett.*, **2008**, *101*(20), 203901.
5. Valentine, J.; J. Li.; T. Zentgraf.; G. Bartal.; and X. Zhang, “An optical cloak made of dielectrics,” *Nat. Mater.*, **2009**, *8*(7), 568-571.
6. Lee, J. H.; J. Blair.; V. A. Tamma.; Q. Wu.; S. J. Rhee.; C. J. Summers, and W. Park, “Direct visualization of optical frequency invisibility cloak based on silicon nanorod array,” *Opt. Express*, **2009**, *17*(15), 12922-12928.
7. Gabrielli, L. H.; J. Cardenas.; C. B. Poitras.; and M. Lipson, “Silicon nanostructure cloak operating at optical frequencies,” *Nat. Photon.,* 2009*, 3*(8), 461-463.
8. Ergin, T.; N. Stenger.; P. Brenner.; J. B. Pendry, and M. Wegener, “Three-dimensional invisibility cloak at optical wavelengths,” *Science.*, **2010**, 328(5976), 337-339.
9. Ma, H. F. and T. J. Cui, “Three-dimensional broadband ground-plane cloak made of metamaterials,” *Nat. Commun.*, **2010**, *1*, 21.
10. Gharghi, M.; C. Gladden.; T. Zentgraf.; Y. Liu.; X. Yin.; J. Valentine, and X. Zhang, “A carpet cloak for visible light,” *Nano Lett.*, **2011**, *11*(7), 2825-2828.
11. Shin, D.; Y. Urzhumov.; Y. Jung.; G. Kang.; S. Baek.; M. Choi.; H. Park.; K. Kim, and D. R. Smith, “Broadband electromagnetic cloaking with smart metamaterials,” *Nat. Commun.*, **2012**, *3*, 1213.
12. Zhang, B.; T. Chan, and B.-I. Wu, “Lateral shift makes a ground-plane cloak detectable,” *Phys. Rev. Lett.*, **2010**, *104*(23), 233903.
13. Smolyaninov, I. I.; V. N. Smolyaninova.; A. V. Kildishev, and V. M. Shalaev, “Anisotropic metamaterials emulated by tapered waveguides: Application to optical cloaking,” *Phys. Rev. Lett.*, **2009**, *102*(21), 213901.
14. Luo, Y.; J. Zhang.; H. Chen.; L. Ran.; B.-I. Wu.; and J.-A. Kong, “A rigorous analysis of plane transformed invisibility cloaks,” *IEEE Trans. Antennas Prop.*, **2009**, *57*(12), 3926-3933.
15. Xi, S.; H. Chen.; B.-I. Wu, and J.-A. Kong, “One-directional perfect cloak created with homogeneous material,” *IEEE Microwave and Wireless Components Letters.*, **2009**, 19(3), 131-133.
16. Zhang, B.; Y. Luo.; X. Liu, and G. Barbastathis, “Macroscopic invisibility cloak for visible light,” *Phys. Rev. Lett.*, **2011**, *106*(3), 033901.
17. Chen, X.; Y. Luo.; J. Zhang.; K. Jiang.; J. B. Pendry, and S. Zhang, “Macroscopic invisibility cloaking of visible light,” *Nat. Commun.*, **2011**, *2*, 176.
18. Liang, D.; J. Gu.; J. Han.; Y. Yang.; S. Zhang.; and W. Zhang, “Robust large dimension terahertz cloaking,” *Advanced Materials.*, **2012,** *24*(7), 916-921.
19. Chen, H. and B. Zheng, “Broadband polygonal invisibility cloak for visible light,” *Sci. Rep.*, **2012**, *2*, 255.
20. Landy, N. and D. R. Smith, “A full-parameter unidirectional metamaterial cloak for microwaves,” *Nat. Mater.*, **2013**, *12*(1), 25-28.
21. Urzhumov, Y.; N. Landy.; T. Driscoll.; D. Basov.; and D. R. Smith, “Thin low-loss dielectric coatings for free-space cloaking,” *Opt. Lett.*, **2013**, *38*(10), 1606-1608.
22. Chen, H.; B. Zheng.; L. Shen.; H. Wang.; X. Zhang.; N. I. Zheludev, and B. Zhang, “Ray-optics cloaking devices for large objects in incoherent natural light,” *Nat. Commun.*, **2013**, *4*.
23. Howell, J. C. and J. B. Howell, “Simple, broadband, optical spatial cloaking of very large objects,” arXiv e-print 1306.0863., **2013**.
24. Houdin, R., The Secrets of Stage Conjuring, Wildside Press LLC., **2008**.
25. Leonhardt, U. and T. Tyc, “Broadband invisibility by non-euclidean cloaking,” *Science.*, **2009,** *323*(5910), 110-112.
26. Xu, S.; X. Cheng.; S. Xi.; R. Zhang.; H. O. Moser.; Z. Shen.; Y. Xu.; Z. Huang.; X. Zhang.; F. Yu.; B. Zhang, and H. Chen, “Experimental demonstration of a free-space cylindrical cloak without superluminal propagation,” *Phys. Rev. Lett.*, **2012**, *109*(22), 223903.
27. Aliev, A. E.; Y. N. Gartstein, and R. H. Baughman, “Mirage effect from thermally modulated transparent carbon nanotube sheets,” *Nanotechnology.*, **2011**, *22*(43), 435704.
28. Schittny, R.; M. Kadic.; T. Bü ckmann, and M. Wegener, “Invisibility cloaking in a diffusive light scattering medium,” *Science.*, **2014**, *345*, (6195), 427-429.