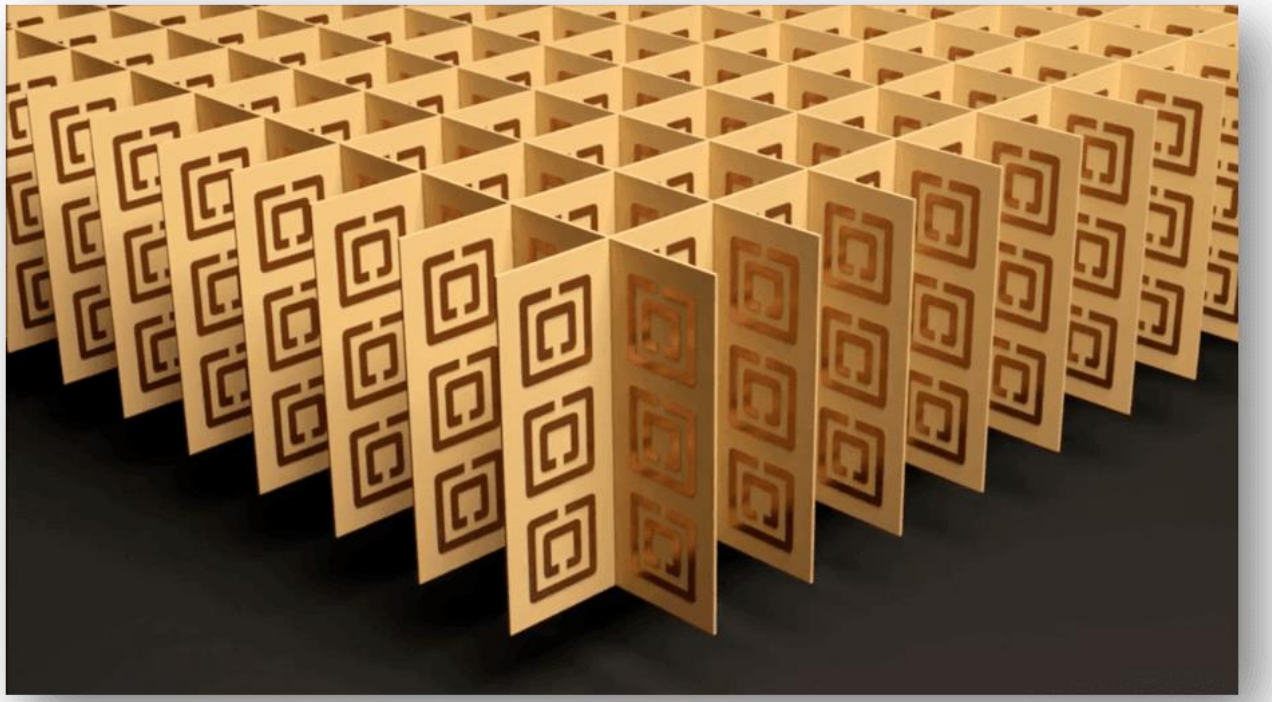
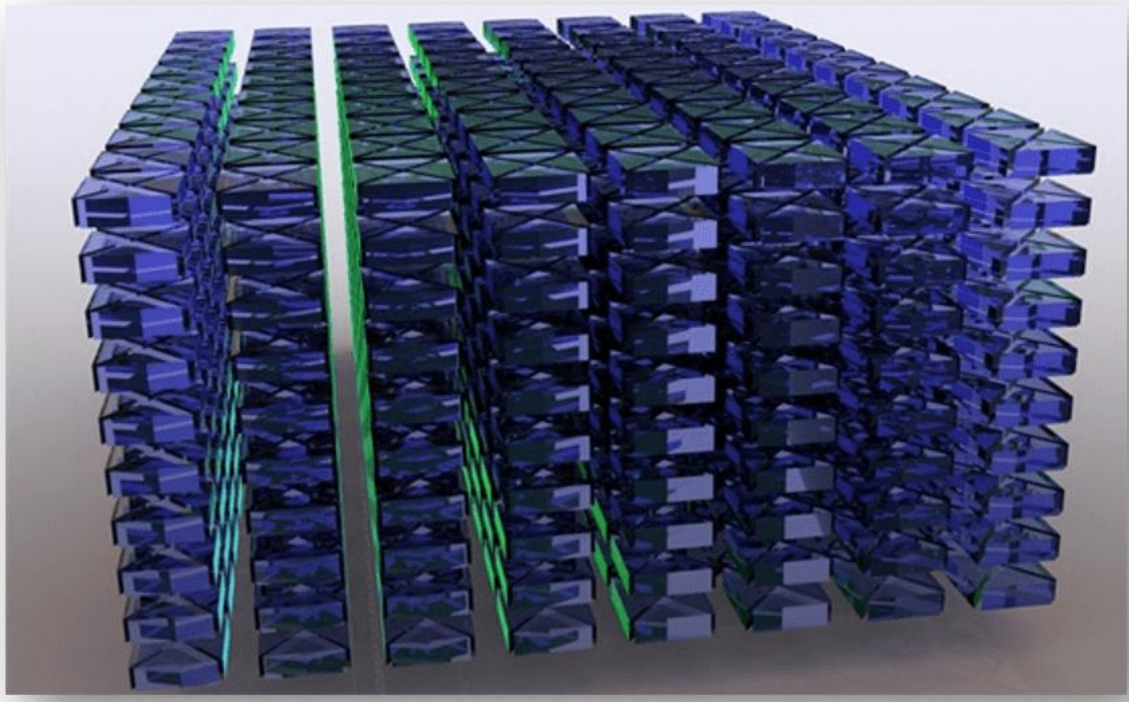
Invisibility Cloaks

Dilraj Ghuman

Metamaterials

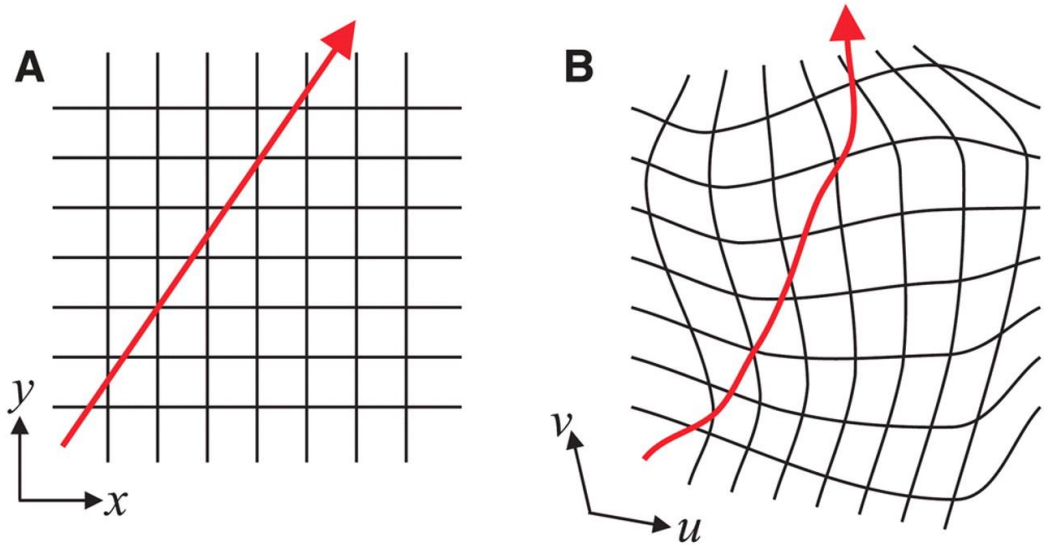




Credit to http://www.metamaterial.com

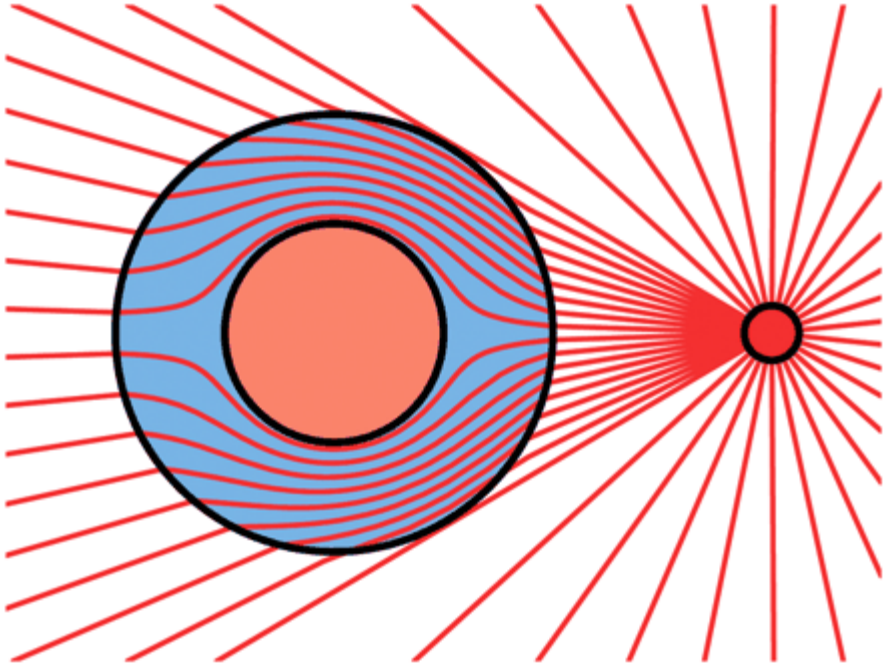
Transformation Optics

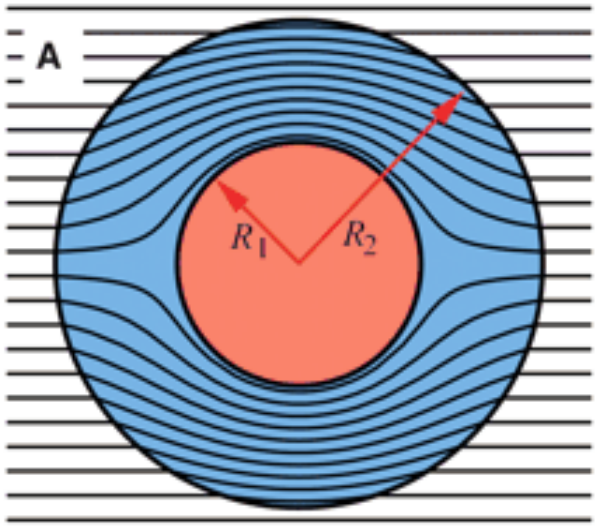
E & M + Metamaterials

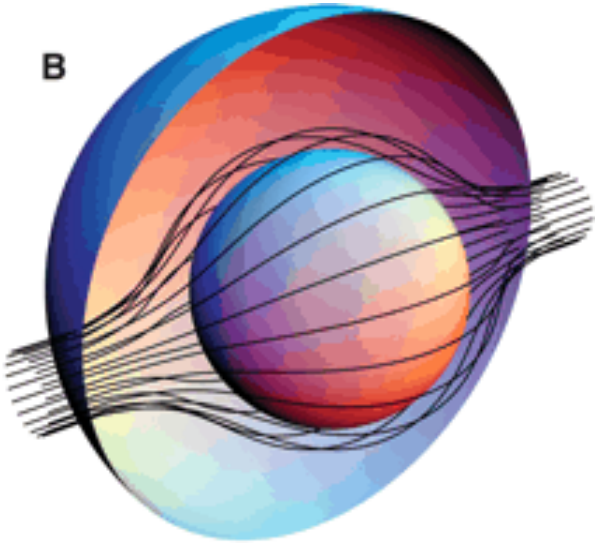


Credit to https://science.sciencemag.org/content/312/5781/1780.full

Transformation Optics







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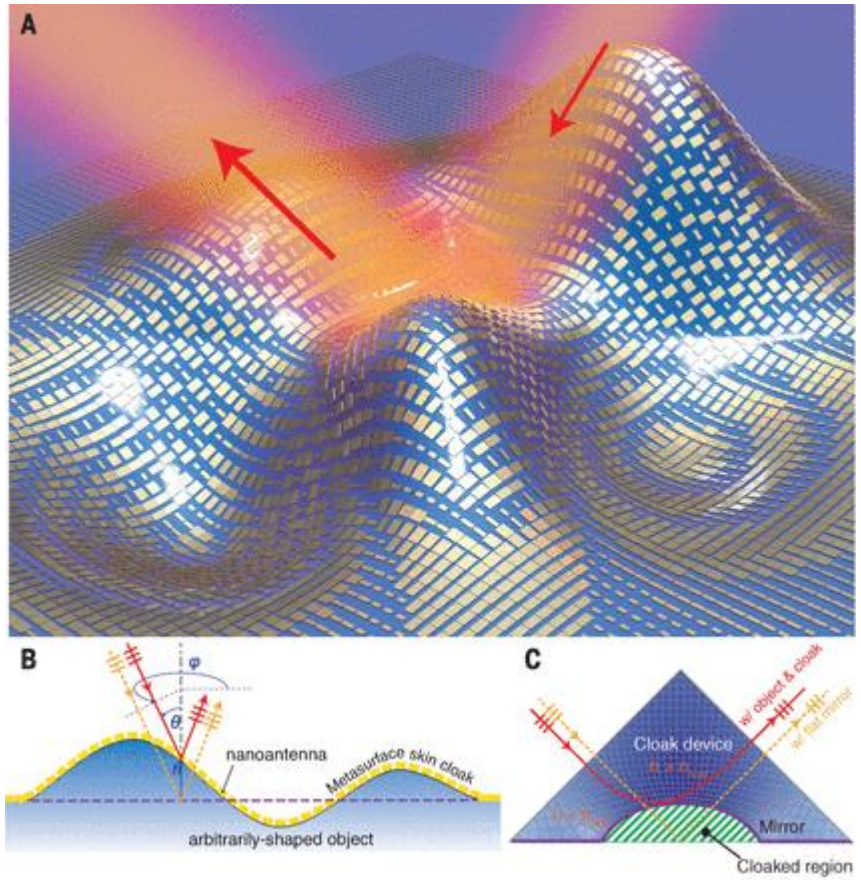
Previously Completed Cloaks

- 2D Microwave Cloak
  - Single-Frequency
  - Transverse Electric Waves (TE)

- Carpet Cloaks
  - Cloaks objects on a plane
  - Uses a reflective surface



Application

arXiv.org > physics > arXiv:1804.05696

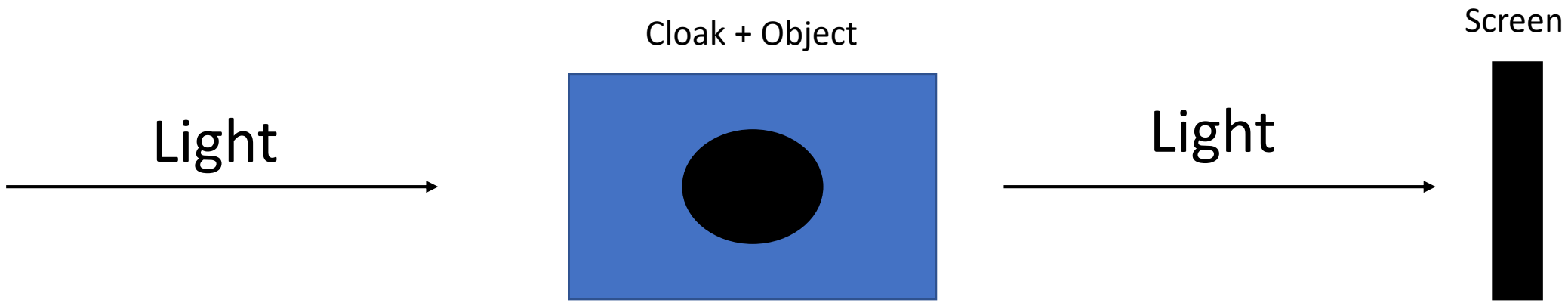
Physics > Optics

Three-dimensional visible-light invisibility cloak

Bin Zheng, Rongrong Zhu, Liqiao Jing, Yihao Yang, Lian Shen, Huaping Wang, Zuojia Wang, Xianmin Zhang, Xu Liu, Erping Li, Hongsheng Chen

(Submitted on 16 Apr 2018)

Set Up



Set Up

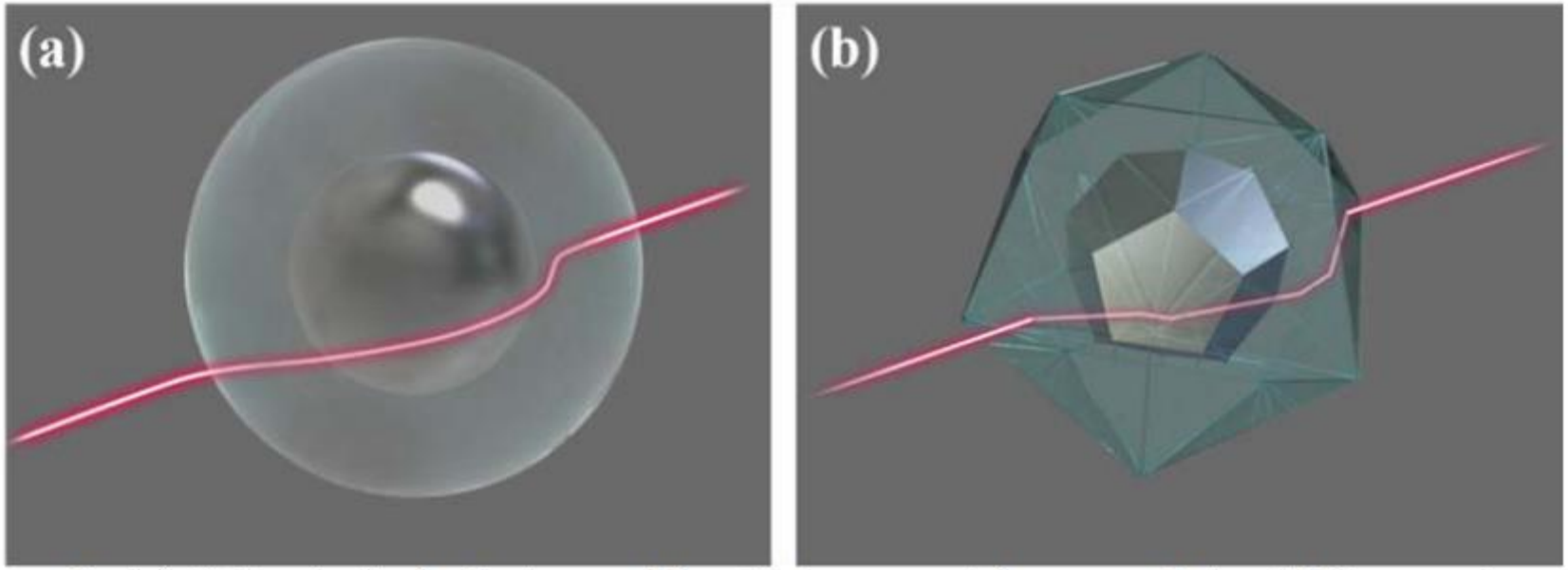
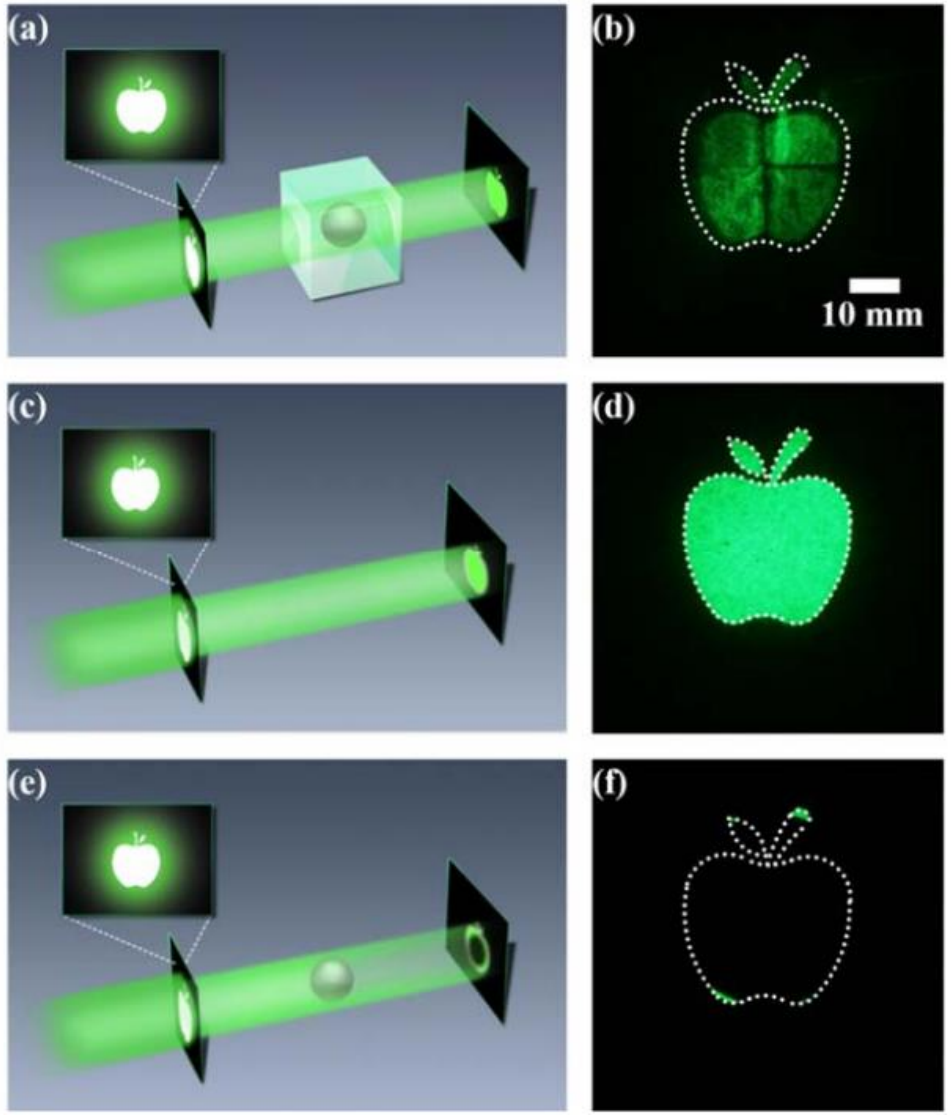


Figure 2. (a) Spherical cloak that guides light smoothly around the hidden region. (b) Polyhedral cloak that bends light at the boundaries of different segments to perfectly bypass the hidden region.

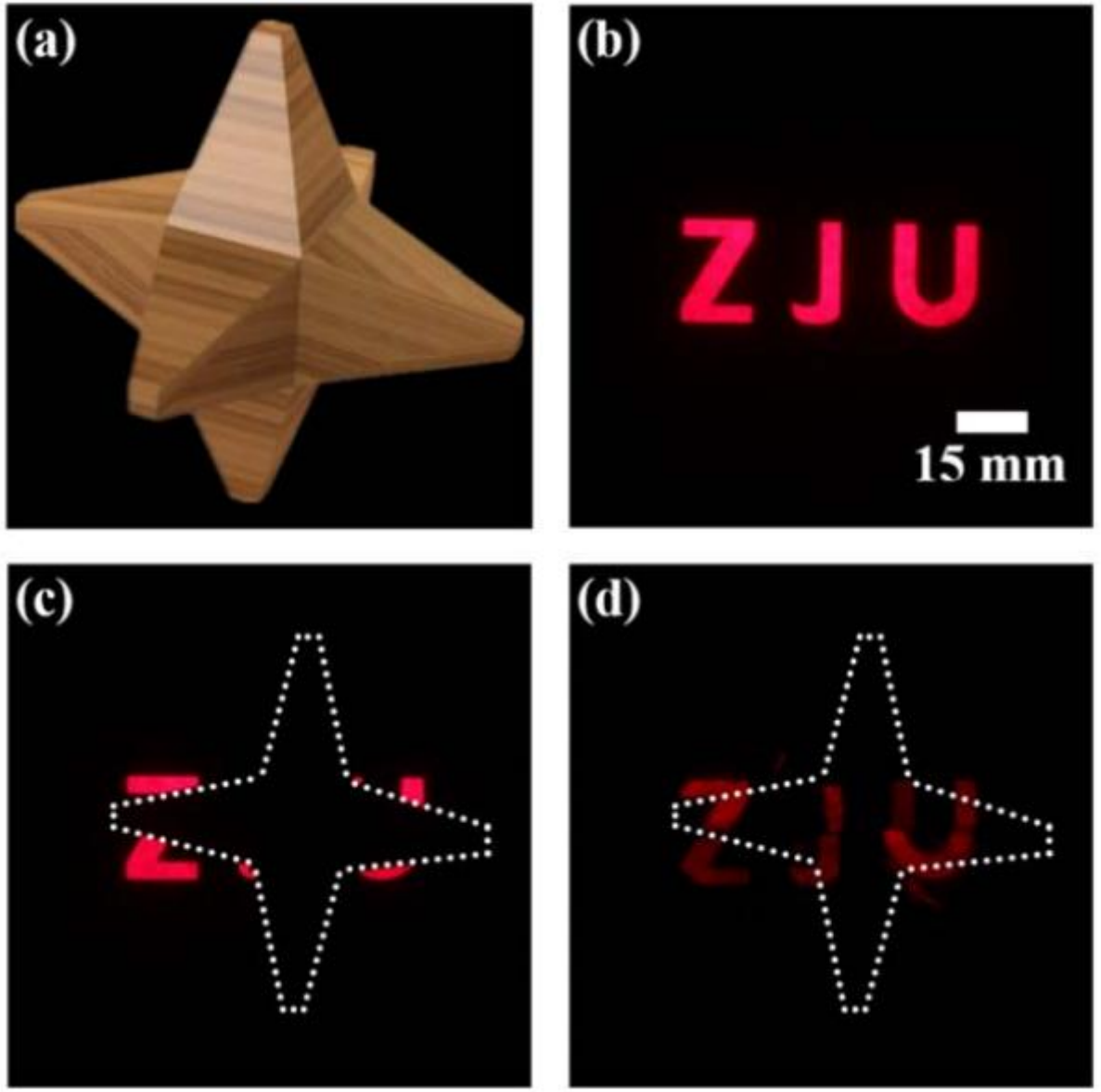
Set Up

- 12 Tetrahedral pieces of glass (ZLaF78) with permittivity 3.61
- Enclosed by 8 heptahedral pieces of glass (ZBaF1) with permittivity 2.63
- Regions between filled with water
- Makes a cube!

Results



Results



Conclusions

- Far from practical consumer invisibility cloaks
- Room for improvement!
  - It would be nice to see the experiment done with a multitude of visible wavelengths
  - Improved to cloak from all viewing angles
- Transformation Optics and Metamaterials are a growing field of study

Transformation Optics

Smooth Maps $u(x,y,z), v(x,y,z), w(x,y,z)$

$$\varepsilon'_u = \varepsilon_u \frac{Q_u Q_v Q_w}{Q_u^2} \qquad Q_u^2 = \left(\frac{\partial x}{\partial u}\right)^2 + \left(\frac{\partial y}{\partial u}\right)^2 + \left(\frac{\partial z}{\partial u}\right)^2$$

$$\vdots$$

$$\mu'_u = \mu_u \frac{Q_u Q_v Q_w}{Q_u^2}$$

$$E'_u = Q_u E_u, H'_u = Q_u H_u, \text{ect.} \qquad \mathbf{B}' = \mu_0 \mu' \mathbf{H}', \mathbf{D}' = \varepsilon_0 \varepsilon' \mathbf{E}'$$

Transformation Optics

$$r' = R_1 + r(R_2 - R_1)/R_2,$$

$$\theta' = \theta$$

$$\phi' = \phi$$

$$\varepsilon'_{\theta'} = \mu'_{\theta'} = \frac{R_2}{R_2 - R_1} = \mu'_{\phi'} = \varepsilon'_{\phi'}$$

$$\varepsilon'_{r'} = \mu'_{r'} = \frac{R_2}{R_2 - R_1} \frac{r' - R_1)^2}{r'}$$