



Modeling Invisibility Cloaking



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Project Description

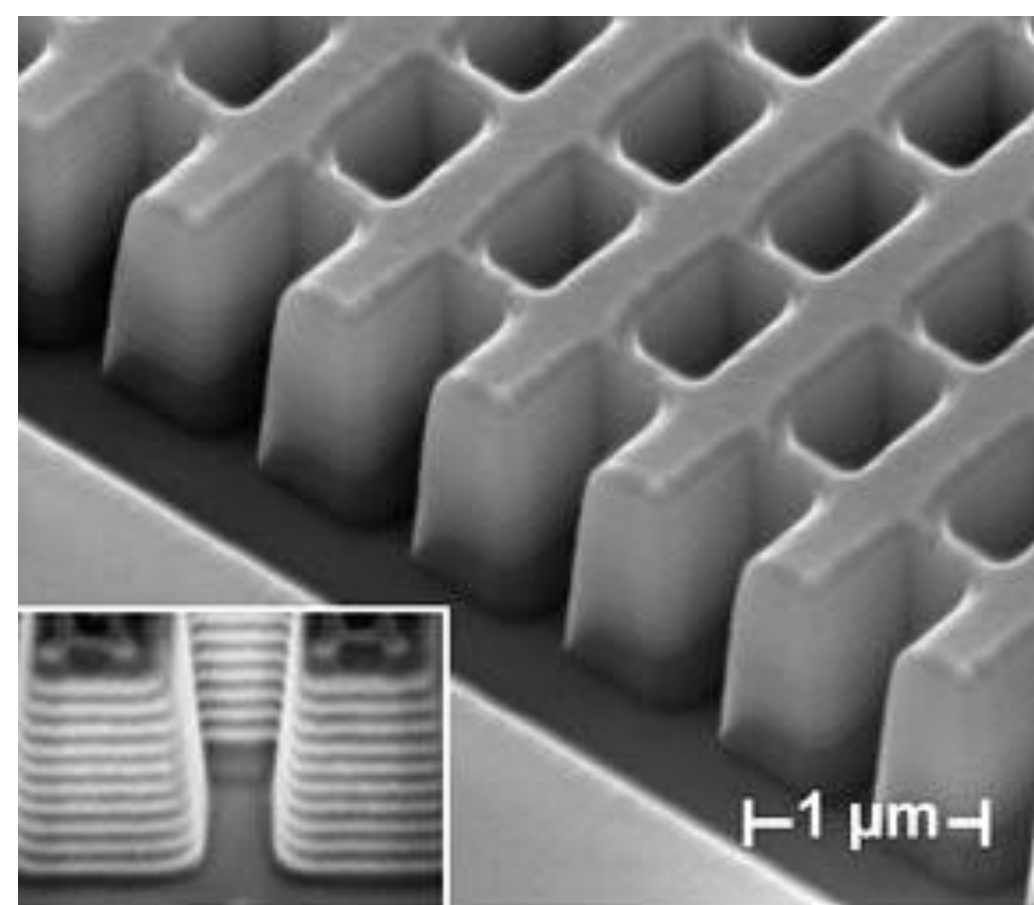
- To explore mathematical methods that have been previously constructed that successfully model the cloaking of objects, otherwise known as “invisibility.”
- To do this, an understanding of metamaterials is necessary to convert our mathematical model into English for practical applications.
- Our final goal was to create a design in Matlab to cloak a human.
- We did this by constructing a coordinate transformation that would simulate a cloak in the shape of a cylinder capped with a hemisphere.

Potential Applications

- In the realms of military application, both covert operations and straightforward military assault would be aided by some form of practical invisibility at various wavelengths. If invisibility is made practical at optical wavelengths, then we are making the object imperceptible to people. If it is managed at radio or infrared wavelengths, then we make it invisible to radar or night vision.

Metamaterials

- Over the past few years, advancements in nanotechnology have made it possible for metamaterials to be created.
- Metamaterials are engineered such that they have small-scale structure that manipulates electromagnetic waves in specific fashions.
- One such fashion would be to provide a negative refractive index.
- In 2008, Xiang Zhang, a scientist at the University of California at Berkeley engineered 3-D metamaterials that negatively refract visible and near-infrared light for the first time.



Scanning electron microscope image of a metamaterial. Note the fine structure that is present

Set up

- Maxwell’s equations retain their properties when a coordinate transformation is implemented .
- Using Maxwell’s equations we were able to create our coordinate transformation with a hemisphere on top.
- We simulated our light rays to reflect off the base of the base of our shape.

Methodology

- We adopted the following coordinate transformation from Pendry’s* journal article:

$$r' = \frac{(R_2 - R_1) r}{R_2} + R_1$$

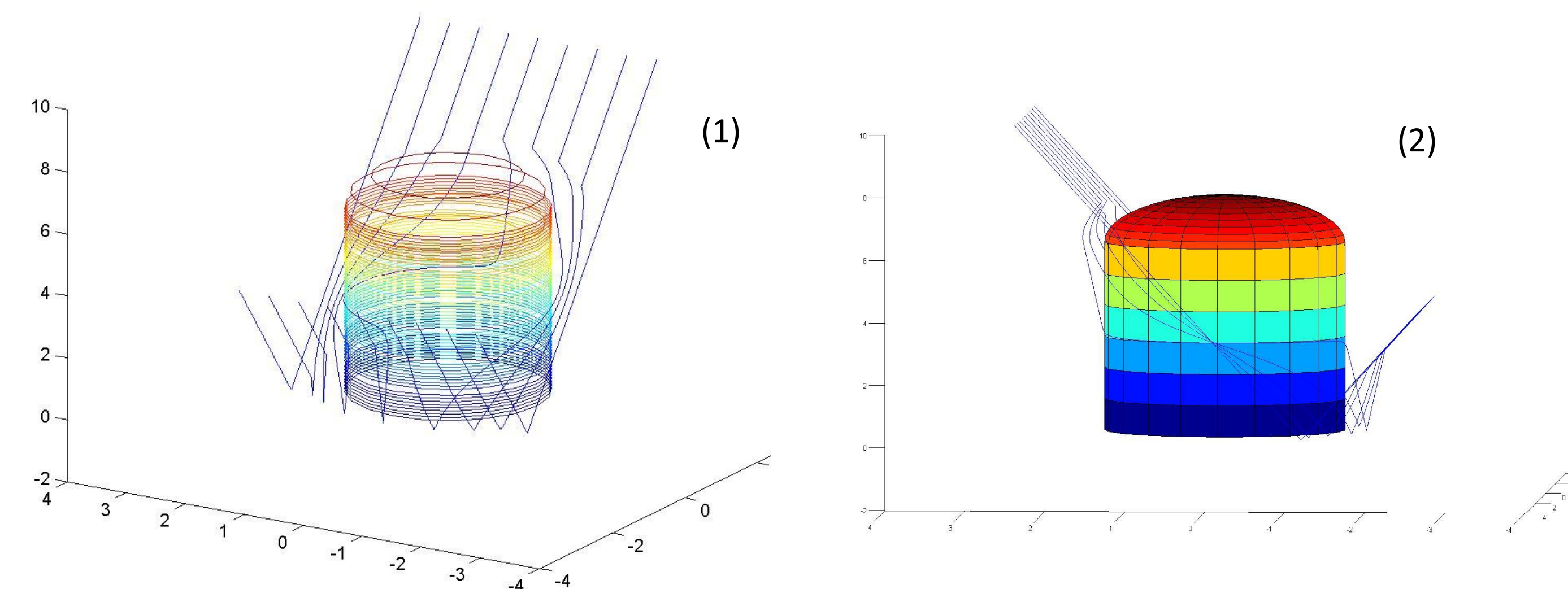
$$\theta' = \theta$$

$$\phi' = \phi$$

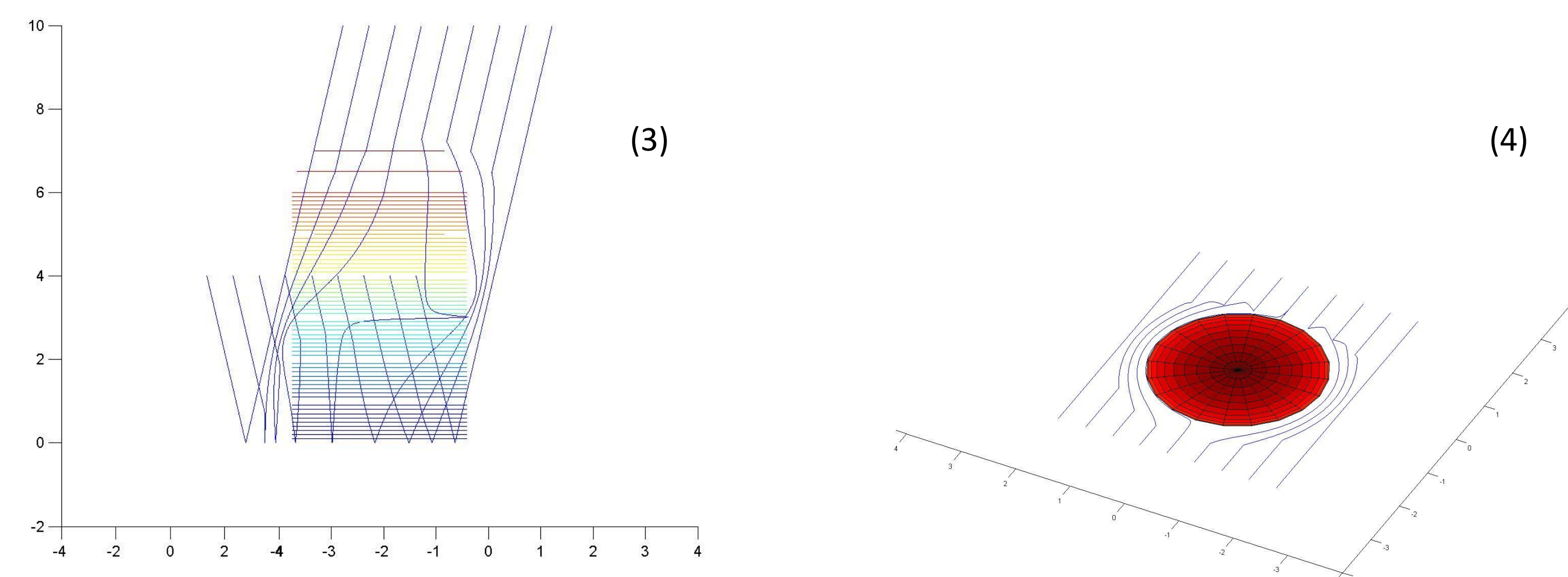
- We applied this transformation to simulated rays of light (3-D ‘straight’ lines) in a specific situation where $R_1 = 1.5$ and $R_2 = 2$, and found that the light rays never touched our cloaked object.

Results

- We encountered problems with our parameterized light rays approaching our hemisphere at the normal angle. Our simulated rays would continue through the center of the sphere instead of undergoing the spherical transformation.
- Although we were unable to remedy the problem, we found it to be negligible for real life applications. The amount of light rays hitting the sphere at the normal compared to those approaching at all angles is insignificant, and our hemisphere would still appear to be cloaked.

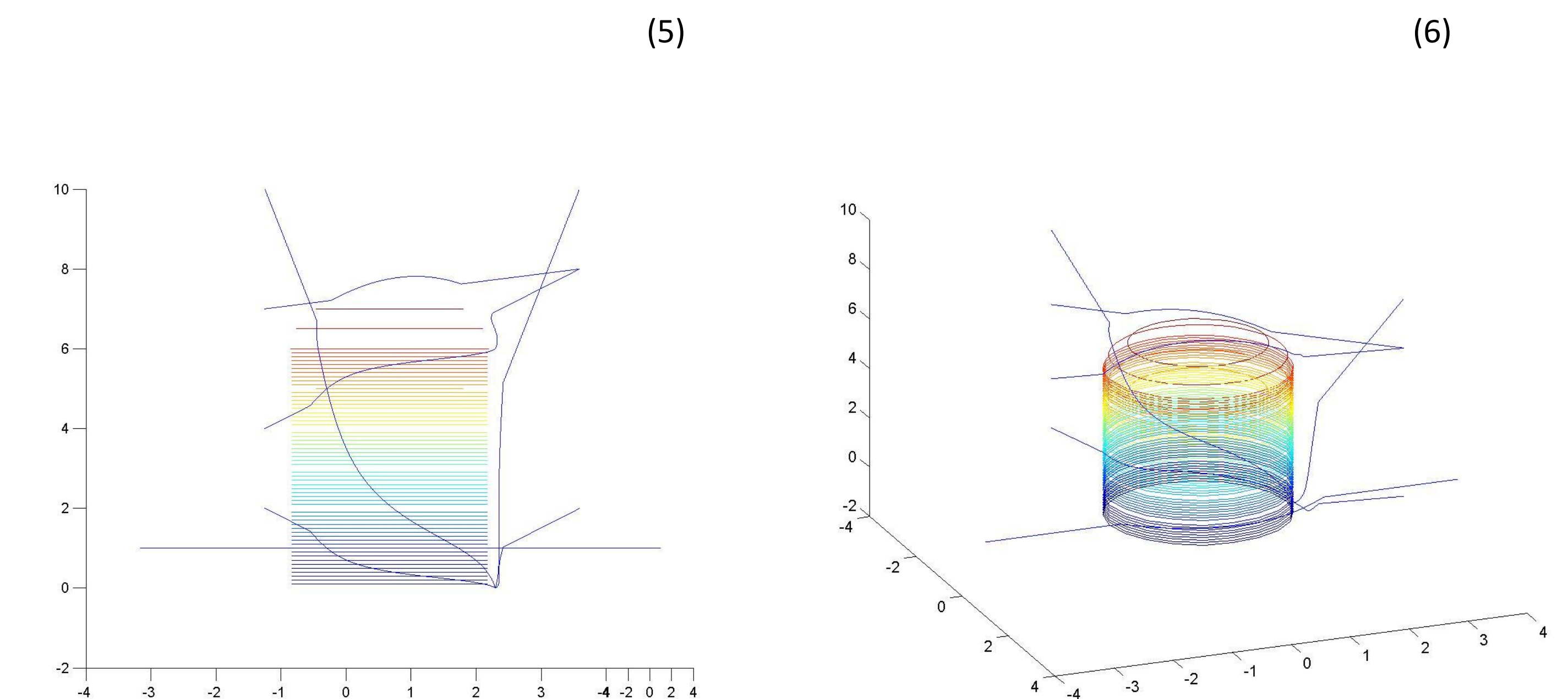


Parallel rays incident on the cloaking surface. Figures (1) through (4) were each taken from a different perspective. Note the light rays curving around the cloak and being reflected off the ground. Figure (4) is a picture taken from directly above the cloaking surface.



Conclusion

- We were successful in modeling a shape that could theoretically cloak a human being.
- Previous research has successfully cloaked an infinite cylinder, however we were able to simulate a surface that could cloak an object positioned on the ground.
- This type of cloaking has never been simulated before.
- Image (1) shows the light rays interacting with the hemisphere, the cylinder, and then bouncing off the ground.
- Figure (2) explicitly illustrates the cloaking surface and the simulated rays bending around the object.
- Figures (3) and (4) depict our rays from different angles.
- Finally, figures (5) and (6) show incident rays of light that interact with different portions of the cloaking surface.
- These last two figures show that our cloak has made any object that is entirely surrounded by the cloak completely invisible!



Figures (5) and (6) show incident rays of light that will interact with the cloaking surface in all possible ways

References

1. Pendry, J. (2009). Taking the wraps off cloaking. American Physical Society. 95 (2).
2. Jason Valentine, Jensen Li, Thomas Zentgraf, Guy Bartal and Xiang Zhang, "An optical cloak made of dielectrics" *Nature Materials*, Vol. 8, 568, 2009

Acknowledgements

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