Macro Optical Cloaking Product Design by Ray Optics

Vinothkumar V* and Raj C Thiagarajan*
ATOA Scientific Technologies, Bengaluru
*ATOA Scientific Technologies Pvt Ltd, 204, Regent Prime, 48 Whitefield Main Road, Whitefield, Bengaluru 560066, India, www.atoa.com, corp.hq@atoa.com

Abstract.

Optical cloaking was considered as fictional. Recent developments shows that macro scale optical cloaking is practical and functional. Brief review of ray optics based macro optical cloaking concepts are given. COMSOL simulations of cloaking devices are detailed. The geometric optics principles used to develop cloak for hiding objects are given. Invisibility of both the object and the cloak is demonstrated using simulations of macro scale systems and without metamaterials. Optical principles such as, Reflection, Refraction, focus, Total Internal Reflection are leveraged using optical components such as mirrors, concave and convex lens, fresnel lens, for creating cloaking. The effect of size, distance, focal length, material combination are investigated for maximising the cloaking region and minimising the size of the device. The results related to the development of Innovative Industrial application of macro cloaking will be detailed.

Keywords: Macro Optical Cloaking,Mirror Cloaking,Refraction,Reflection,Cloaking by lens,Ray Optics,Geometrical cloaking,CAE Simulation,Multiphysics CAE.

1.0 Introduction.

One of the focus area of optical metamaterials research is stealth technology such as cloaking. Developments in experimental optical cloaking is based on transformation optics, metamaterials and patterned dielectrics with the use of quasi-conformal mapping [1-4]. Experimental demonstration of broadband, phase and amplitude cloaking at visible spectrum is a challenge due to limitations in nanoscale fabrications. In this paper, ray optics based marco cloaking concepts are investigated for practical Industrial applications. Optical principles such as Reflection, Refraction, focus, Total Internal Reflection are leveraged using optical components such as mirrors, concave and convex lens, fresnel lens, for creating cloaking region, which makes the object hidden. COMSOL based numerical parametric models are developed for cloaking product design for industrial applications.

2.0 Ray Optical Cloaking Simulations using COMSOL MULTIPHYSICS®

Electromagnetic wave propagation can be simulated using wave or ray optic formulations. In this paper, we design optical products with feature size much greater than the wavelength of optical spectrum and hence Ray optics module is considered for numerical investigation. The Geometrical Optics interface under Ray Optics is used to compute the trajectories of electromagnetic rays for performance evaluation macro optical cloaks.

Reflection, Refraction, Focus and Total internal reflection based macro optical cloaking concepts are simulated. Simple optical components such as mirror, lens, prisms, sheets, slabs are used to construct the cloaking products.

2.1 Model Definition.

The figure.1 represents the CAD model of reflection based cloaking.Normal mirrors are used here to make this cloak.The mirrors arranged in a right angle to each other.The refractive index of the mirror is 1.5 and cloaking take place in an air medium whose refractive index is 1.002.

The figure.2 represents the CAD model of refraction based cloaking.In this method tow L shaped glass tanks are filled with water and separated in a certain distance.The refractive index of water is

1.33 and the cloaking was takes place in an air medium whose refractive index is 1.002.

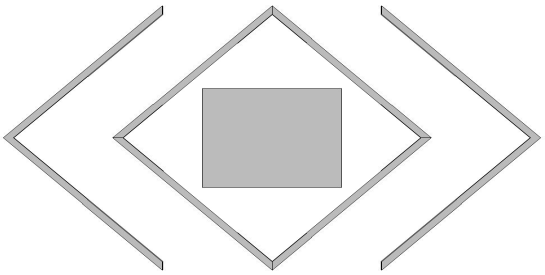

Figure 1.CAD model for Reflection based Cloaking

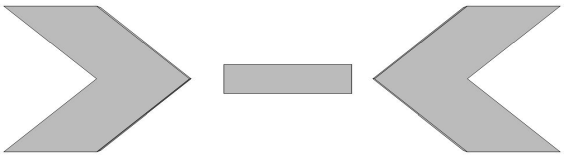

Figure 2.CAD model for Refraction based Cloaking

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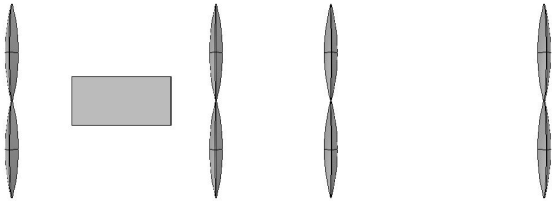

Figure 3.CAD model for Lens based Cloaking.

The figure 3 represents the CAD models of lens based cloaking.Spherical concave and convex lens are used here.The refractive index of lens is 1.5.

2.2 Governing Equation.

The following differential equation is implemented for solving the Ray Tracing physics environment of COMSOL Multiphysics.

$$\frac{dq}{dt} = \frac{\partial w}{\partial t}\ ,$$
$$\frac{dk}{dt} = -\frac{\partial w}{\partial q}$$

For geometric optics,the angular frequency

$$(\omega) = \frac{c|k|}{n}$$

where n is the refractive index of the material.

$$n = \sqrt{2 - (\frac{r}{R})^2}$$

where, r is the radial coordinate from the center of lens and R is the radius of the lens.

3.0 Results and Discussion.

The Ray optical simulation results are shown in Figure 4 to 7. Figure 4 shows, the ray optical trajectories for reflection based cloak using simple mirrors.The black region in the figure 4 is the cloaking region . The ray trajectories from background object to the observer around the clock is shown.Figure 5, shows the macro clocking by refraction. The lens based clocking results are shown in figure 6. The black region between the rays are cloaked, in all the figure. The parametric numerical models helps to optimise the design parameters for perfect cloaking. Figure 7 shows a practical device fabricated based on the simulations results of Figure 4 (reflection based cloak).The black colored Region was cloaked and the person sitting behind the cloaking region is visible.

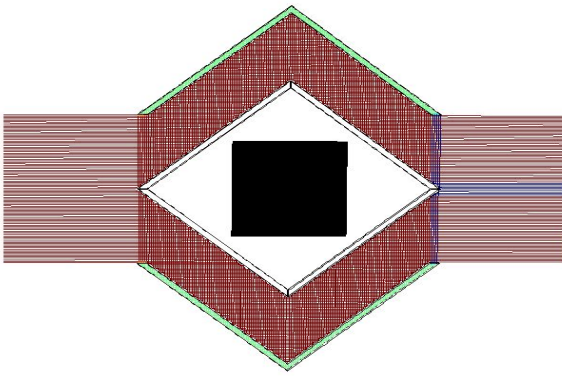

Figure4. Reflection based Cloak.

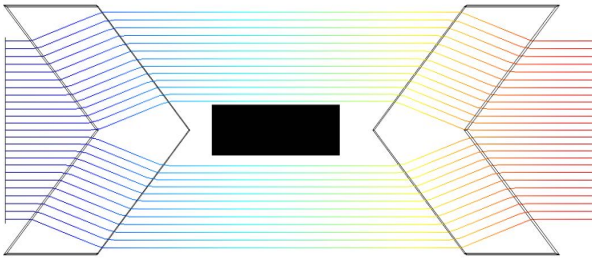

Figure 5.Refraction based Cloak.

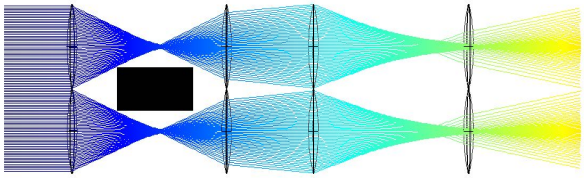

Figure 6. Lens Based Cloaking.

Figure 6.Fabrication of Macro Cloak based on Reflection.

4.0 Conclusions

A brief introduction to ray optical cloaking was given. Optical CAE simulation for practical cloaking was shown. Practical prototype demonstration shows that it is possible to make a macro level cloaking without using metamaterials. The unidirectional cloaking was fabricated using commercially available material such as mirror, lens and water. Simple applications include cloaking of unwanted objects for a pristine natural background view and many industrial applications.

5.0 Acknowledgement

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6.0 References.

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