Development of Augmented Reality Lightguide

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Introduction

Augmented reality (AR), which developed out of virtual reality (VR) technology, is set to be a major contender technology in next decade. Both technologies have now created a domain known as mixed reality (MR) or X reality (XR) where both techniques are combined in a sensible fashion. It is believed by many, that these technologies will provide unique way for users to interact with information that will outpace the usual touchscreen interface available today with smart phones. Since these technologies will eventually find great application in near future. There is significant interest in research in the design of these devices such that they overcome the setbacks that these devices have encountered so far.

The designs I have studied use some optics (eyepiece) to channel light into the lightguide. Within the light guide a coated surface reflects the light to begin the light guiding process. Then, a diffracting structure are required to finally redirect the light to the location of the human eye and produce the immersive experience. A typical challenge with this type of the design is the low field of view and the loss of light. But it can be significantly lighter in weight compared to other designs such as the ones with freeform optical elements. It is required that we seek towards increasing the (FOV), while making the device as light in weight and significantly immersive in the optical experience.

The diffractive techniques use deep slanted diffraction gratings (i.e. Nokia technique now licensed to Vuzix and now used by Microsoft for its Hololens project). This technique uses slanted gratings as shown in **Figure 1**, to incouple collimated light entering the waveguide at an angle, then, the light travels through the waveguide using the principle of total internal reflection.AR devices which are wearable displays are compelling because they offer the ability to display video, navigation, messaging, augmented reality applications, and games on a large virtual screen hands free. However, any such device will need to be affordable and should have a form factor that is attractive enough so that users will easily adopt it [1].

Another recent development in this field involves the use of computer-generated holograms. With the rapid development of computer technology, holograms can now be calculated by algorithms. In order to display computer-generated holograms (CGHs), a spatial light modulator (SLM) is employed. Compared to traditional holographic technology, CGH has three advantages [2]. There are also other techniques that can be introduced to create light guide devices which have switching properties with the use of liquid crystals and suspended particles. These proposed techniques are creating new solutions for this emerging technology [3]. In the next sections of the paper we will discuss, the governing theory, and the setup of our device and show how we can design for proper light travel within the device, how light is extracted with diffractive optical elements and redirected to eye and how we have quantified the thermal properties of the device.

Theory and Set-up

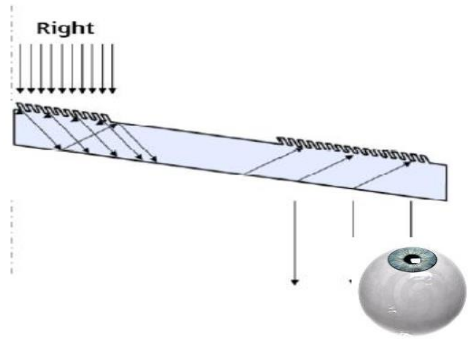

Figure 1. ***The schematic for the slanted grating technique invented by Nokia and licensed to Vuzix. An early Nokia prototype based on this principle being worn on the right [1]***

Governing Equations and Numerical Model

I used the ray optics module of Comsol5.3a and coupled it to the heat transfer module in order to estimate some hot spots in the material.

$$\frac{d\mathbf{q}}{dt} = \frac{\partial\omega}{\partial\mathbf{k}} \quad \frac{d\mathbf{k}}{dt} = -\frac{\partial\omega}{\partial\mathbf{q}} \tag{1}$$

The equations above represent the first order equations describing the ray travel, where **k** is the wave vector, ω is the angular frequency, and **q** is the position vector, while t, is time. A grating was also introduced to finally diffract the light as it exits the lightguide into a human eye. The equation describing the diffraction process is given by

$$m\lambda_0 = d(n_2 \sin\theta_m - n_1 \sin\theta_i) \tag{2}$$

The transmitted light wave of diffraction order m corresponding to an angle Θ_m with the boundary normal so that where λ_0 is the vacuum wavelength, d is the grating constant, θ_i is the angle of incidence, and n_1 and n_2 are the refractive indices on the incoming and outgoing sides

$$\rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = Q$$

$$\mathbf{q} = -k\nabla T \tag{3}$$

In equation 3, is the well-known heat equation, where ρ is the density of the material, *Cp* the heat capacity at constant pressure, *T*, the temperature, **q,** a power flux term and Q a heat source term.

Simulation Results and Discussion

The simulation task involves primarily finding a lens design that will collimate the light. It is assumed that at the point where the rays propagate from will sit a micro display that will contain the information that will be conveyed to the eye. The rays should go through the lens and emerge significantly collimated and should strike the reflecting surface within the wave guide at the right angle that will ensure the rays to bounce back and forth in total internal reflection, being directed to the eye at the appropriate distance. We must consider the typical inter pupillary distance factor that into our design and simulation. The initial design task involved simulating the system for a relatively thick and long waveguide the optimize the design such that it can represent a device that will of appropriate size.
A pre-optimize design is shown below in Figure 2. It shows how light is made stay within the guide by TIR. This design does not include diffractive optical elements.

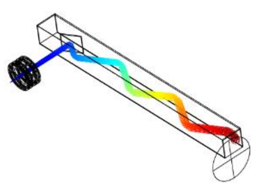

Figure 2**.** Simulation of light propagation within an AR/VR device

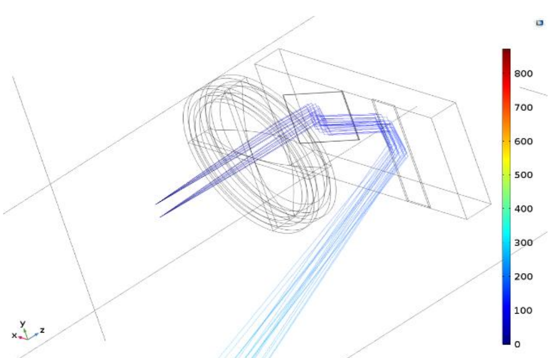

Figure 3. Optimized design, with diffractive DOE

We can vary the number of lines/meters on the grating and change the emergent angle and the field of view of the device.

In the designs considered d the grating constant is kept between 400-600lines/meter and the order of diffraction m=0, and ±1. For this design the thickness of the lightguide has reduced to about 10mm. It is important that

When the heat equation and taking into consideration and the material constants we can estimate the temperature of the system. It is found that the temperature will rise from 298K to about 337K at its hottest spots, as seen in Figure 4.

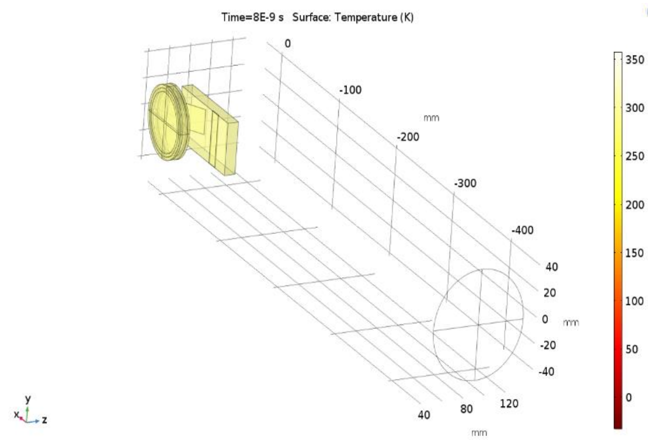

Figure 4. Thermal Analysis of Design 3

The total estimated mass in grams is about 186g, and its FOV is about 36 degrees. This optimized design which includes the catalog lenses from Thorlabs AC508-060-A light guide material made of BK7.

References

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Acknowledgements

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