

PROGRAMMED MICRO MIRRORS USED FOR IMAGING SECURITY DEVICES FOR CURRENCY AND BRAND AUTHENTICATION

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Background of the Invention

For years, holograms and lens features have been used for security devices in currency, brand authentication and brand protection, as well as high security documents. Holograms are becoming increasingly less secure, due to the rise in technology, programming and general availability of programs that allow one to create holograms easily. In many cases, the cheaper dot matrix holograms are “good enough” to simulate many of the effects of the more expensive elaborate holograms. And, while lens features done properly can be more secure, there is a need for new technology to combat the currency and product counterfeiting. Ideally, new technology would have attributes that are not possible with holography or micro-lenses.

Summary of the Invention

The idea of the invention is to “write” images with light in spatial planes above and below the surface of the micro-mirrors. Text, imagery, and so forth can be written with ambient light by focusing the micro-mirrors to different spatial planes. Conversely, the technology can then “reverse” to the viewer by having the “bright” pixels go to “dark” and the backgrounds reverse from “light” to “dark” with a change of perspective. Also, since the technology is made of mirrors (made from thin aluminum, silver or gold depositions) it will work from two sides in a film process. This type of image cannot be done with holography.

The technology can be embossed into films, metallized, and then processed into currency threads, foil stamps, labels and packaging. It can also be directly stamped onto coins or other metallic surfaces. Color can also be added by some reflective ink printing methods or with dielectric Nano-structures (plasmonic resonance).

The Program and Algorithms

The basic idea of the micro-mirror invention is to use ambient light and a plane containing many small mirrors, and to aim the ambient light reflected off the mirrors toward a desired point in space above the plane that contains the mirrors. This is called the 1st layer image and is defined by artwork that has light or dark pixels to be produced in layer 1. By carefully selecting the mirrors within a circle defined by the intersection of the cone defined by an apex angle and a pixel from layer 1 as the apex of the cone, a mirror is aimed toward the cone apex from various mirrors in the circular base of the cone so that the result effect is a point source of light floating above the level of the mirror plane at the location of a pixel, containing the mirrors. Using a computer algorithm on a pixel-by-pixel basis completes this process. If the pixel in the 1st layer is a dark pixel, no rays will be aimed toward it. In addition the program has the capability of using a 2nd layer of pixels that acts as a mask for the first layer of pixels so that various portions of the pixel image at level one are "hidden" or visible depending on the viewing angle. The algorithm that generates the 1st layer of floating pixels looks at the rays aimed to the pixel in the first layer and the continuation of the rays to the 2nd layer. The intersection location in the 2nd layer is calculated and is searched for nearby dark pixels of the 2nd layer (mask layer). If dark pixels are found in the intersection area on the 2nd layer, the mirror that reflected that ray to the 1st layer is not used to aim the ray at that pixel to the 1st layer. Thus there is a masking effect of the mask layer as is desired. To form a mask that appears to "float" over the pixels in layer 1, some pixels of layer 1 will have partial cones of pixels depending on the mask geometry defined by the pixels on/off of the 2nd layer, and the angle the pixels are viewed. As the viewer's eye is moved (or the mirror assembly tilted to the viewer), pixels of the 1st layer will change brightness and appear or disappear from view in a way that causes the mask to appear to move.

To insure uniform illumination across pixels, during the aiming process as described above, only one of the available mirrors is used in each pixel's cone of acceptance and the mirror is selected at random from the available mirrors in the cone of acceptance. After the direction cosines of the selected mirror are calculated the mirror is marked as "no longer available for use by any other pixel". The program moves on to the next pixel and the same sequence of events happens until all the pixels are used. At that point the entire sequence of pixels is again used to pick up one of the available mirrors for each pixel. After a number of cycles of the pixels all the mirrors are used depending on the image and mask patterns. If some mirrors cannot be used because of the geometry of the image layer and mask layer, they will be aimed out of the viewing zone.

The program allows the user to choose the values of the spacing of image levels from the mirror plane, as well as pixel cone angles, mirror sizes and pixel pitches. These all will be optimized to make the best image to present to the viewer. The inputs to the program currently are the pixel image files for layer 1 and the mask for layer 2. However, there are also capabilities for the program to make its own test input layers. The output of the program is a data file containing mirror locations and the direction cosines of each mirror in a format suitable for a vendor to make the mirrors.

The program allows the user to see the input files, ray traces to different levels, and the expected image seen on the retina of a viewer. Tracings can be done using input cones of light on the mirrors to see the affects ambient light distributions on the viewer's retina.

The following images and captions show some of the workings and results of the computer program as it now stands.

User Inputs		Calculated Results	
Ice Units (microns) (mm) etc	microns	N Dark Pixels	400
Number of Levels to Use >0 and <= 3	2	N White Pixels	2000
Level 1 Height	10000	N Missing Pixels	2500
Level 1 Cone Ang Deg	30	N Dark Mirrors Generated	1312
Level 1 Angle Offset	0	N White Mirrors Generated	2000
Level 2 Height	20000	N Unused Mirrors	0
Level 2 Cone Ang Deg	15	Future	Future
Level 2 Angle Offset	0	Future	Future
Level 3 Height	30000	Pixel N in X	25
Level 3 Cone Ang Deg	20	Pixel N in Y	25
Level 3 Angle Offset	0	Num of Mirrors For Above Pixel	2000
Mirror Size X	50	Mirror N in X	27
Mirror Size Y	50	Mirror N in Y	27
Image Focal Points X Pitch	254	Num of Pixels For Above Mirror	300
Image Focal Points Y Pitch	254		
Number of Test Pixels in X	50		
Number of Test Pixels in Y	50		
Test X,0 none,1W,2 half W,3 one Pixel	2		
Future	0		
** Use Positive Image			

Main Menu

The main menu shows some of the inputs the user can make such as pixel pitch, level values, and cone angles for pixels mirror size and selection of test patterns.

The right side of the menu shows some of the details of the calculations such as the number of mirrors that are dark (aimed away from pixels), numbers of mirrors used, calculation, algorithm used, time required to calculate direction cosines of mirrors.

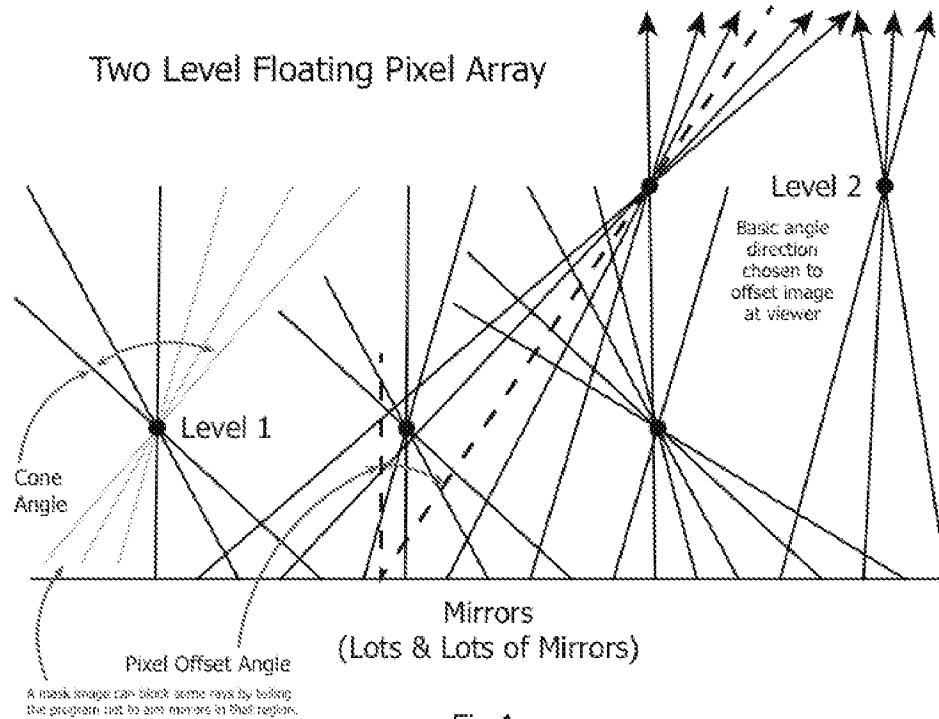
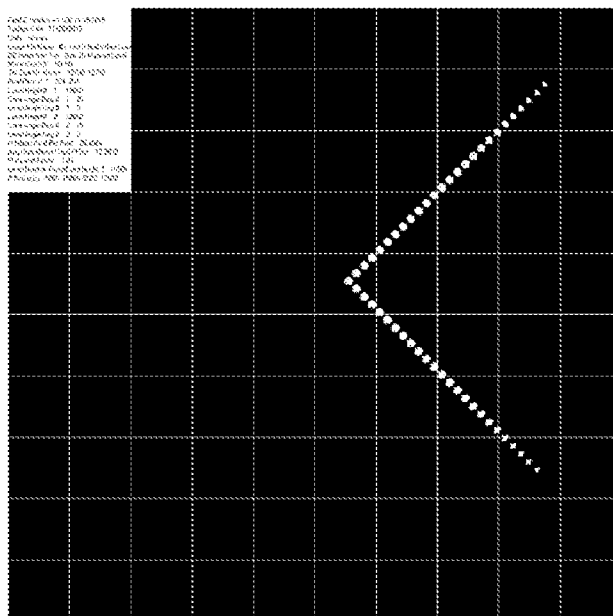
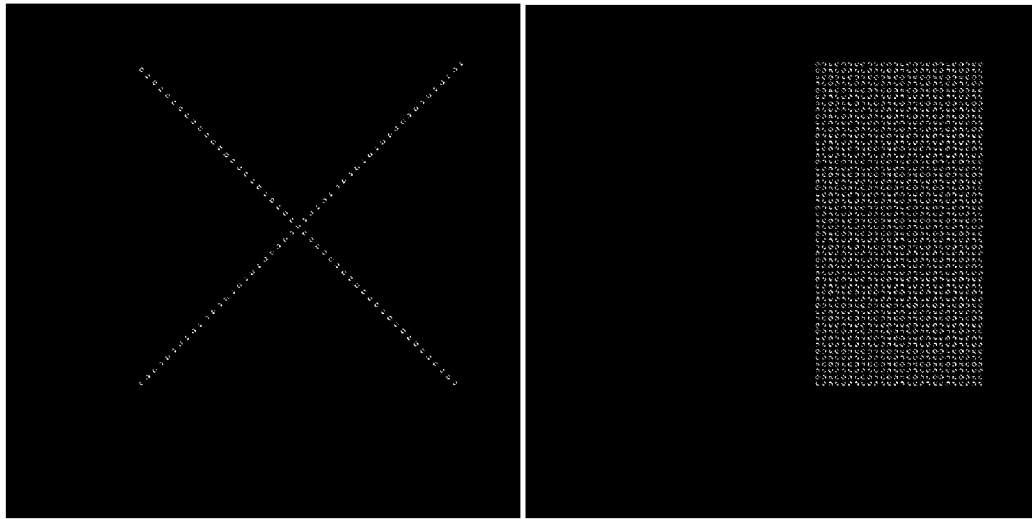


Fig 1.

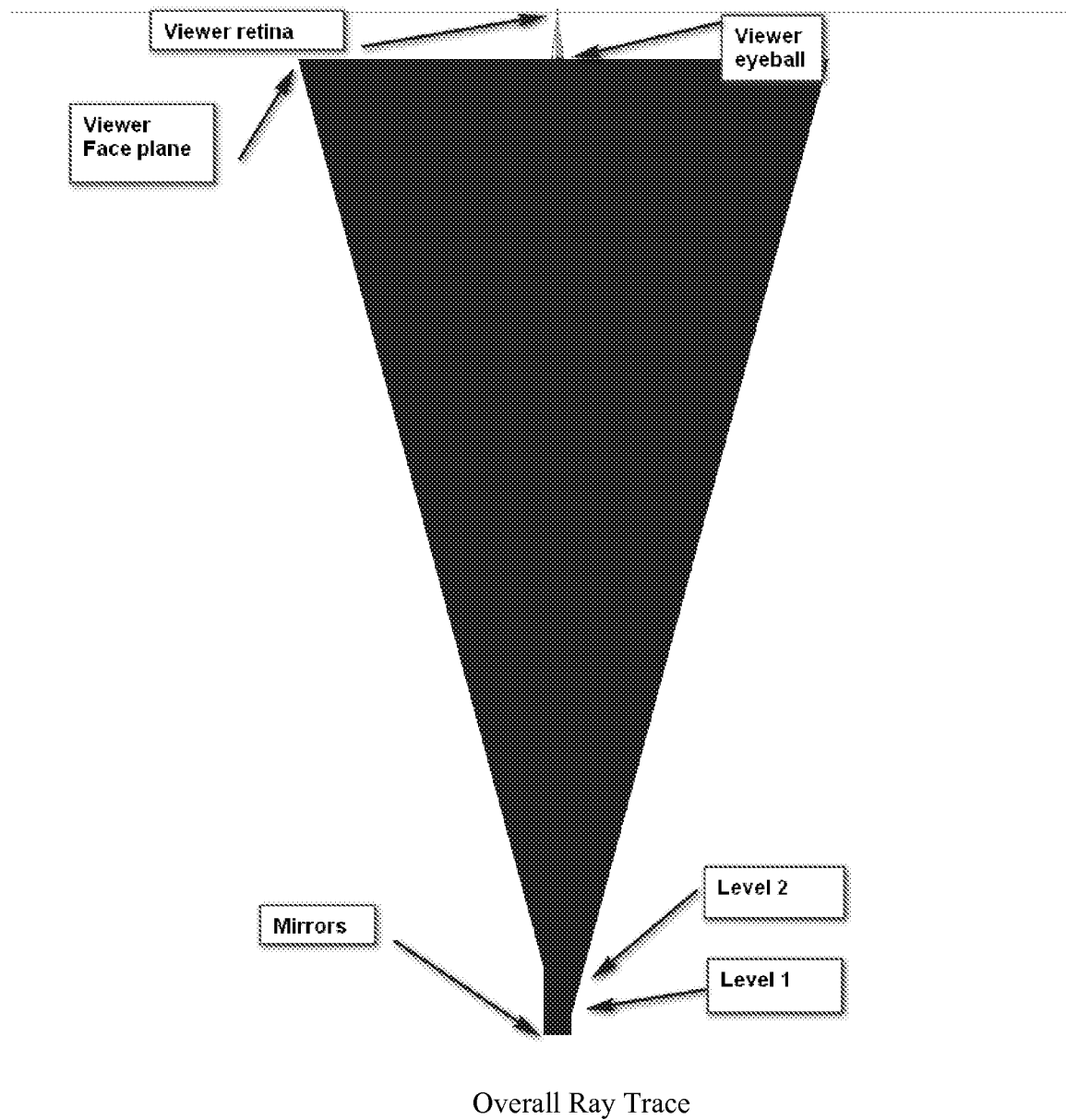
9-17-15

Two images below are the internally generated levels used for testing the program

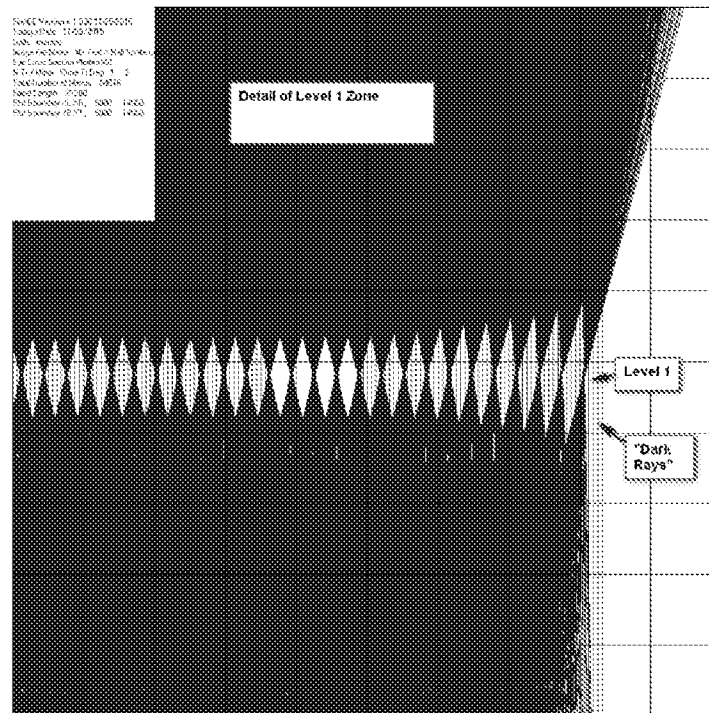


The partial "X" shows the effect of the mask on blocking part of the image.

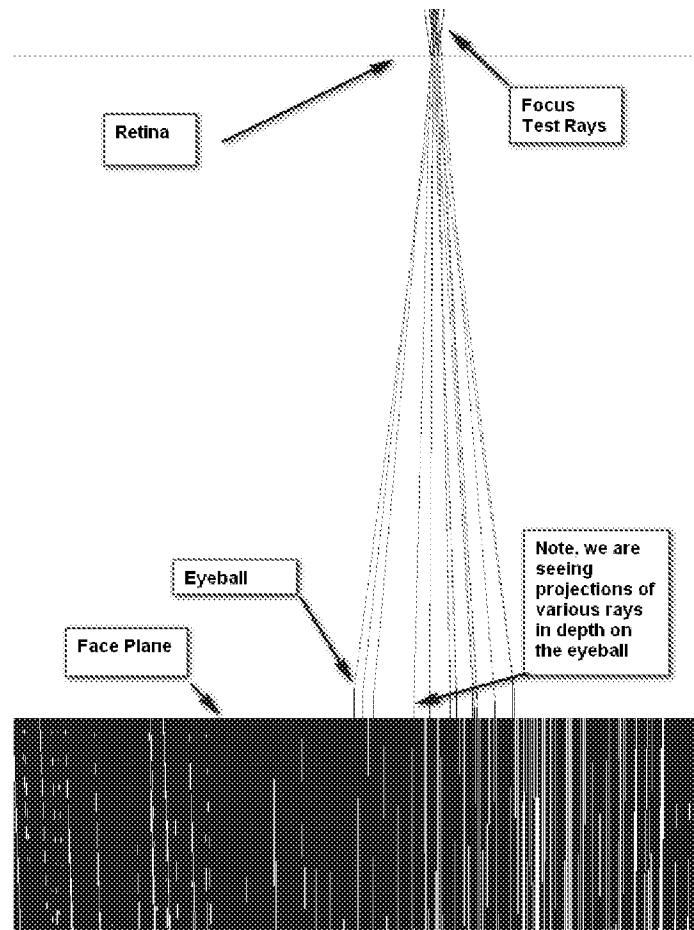
The image below is an overall ray trace from the mirrors to a short distance above level1 to show the masking effect of the 1/2 right side transmitting mask.



Below are details of the ray tracing.



The above plot shows details of the ray trace near level 1. We see converging rays from the mirrors below meeting at the floating pixel level 1.



The above is a detail of the retina area of the viewer. We see rays that have reached the eyeball and are focused on the retina.

One of the important analysis tools the program has is to be able to evaluate the image as seen by a viewer. To do this, a ray tracing part of the program was incorporated to view the image on a simulated retina. Thus the effectiveness of the mask can be analyzed by putting the viewer's eye in various locations (equivalent to tilting the mirror plane) and plotting the ray traced image on the simulated retina. The main menu for specifying the parameters is below.

1. Pick Parameters for 3D View

Save Plot Data

Cross Section Selections: ☐ Not used ☒ XY Plane Rays ☒ XZ Plane Rays ☐ YZ Plane Rays

Eye Location XYZ (z=18 inch 457200 microns)

Eye Focal Length (22 mm 22000 microns)

Eye Index of Refraction (1.333)

Eye Aperture (6.5 mm 6500 microns)

Eye Lens Radius (5.55 mm 5550 microns)

Number of Rays to Trace per Mirror(<10,000)

Cone Angle of Mirror Trace (Deg)

☒ Plot Traced Ray Intersections

☒ Plot Captions

☐ Plot Mirrors

☐ Plot Pixel Cones

☐ Plot Mirror Boundary

☐ Plot Grid

Retina Plot Selections:

☒ Use Plot 1

☒ Use Plot 2

☒ Use Plot 3

☒ Use Plot 4

3D X Width 3D Y Height

3D X Width 3D Y Height

3D X Width 3D Y Height

3D X Width 3D Y Height

Eye Plot L 1 Eye Plot R Eye Plot B Eye Plot T

Eye Plot L 2 Eye Plot R Eye Plot B Eye Plot T

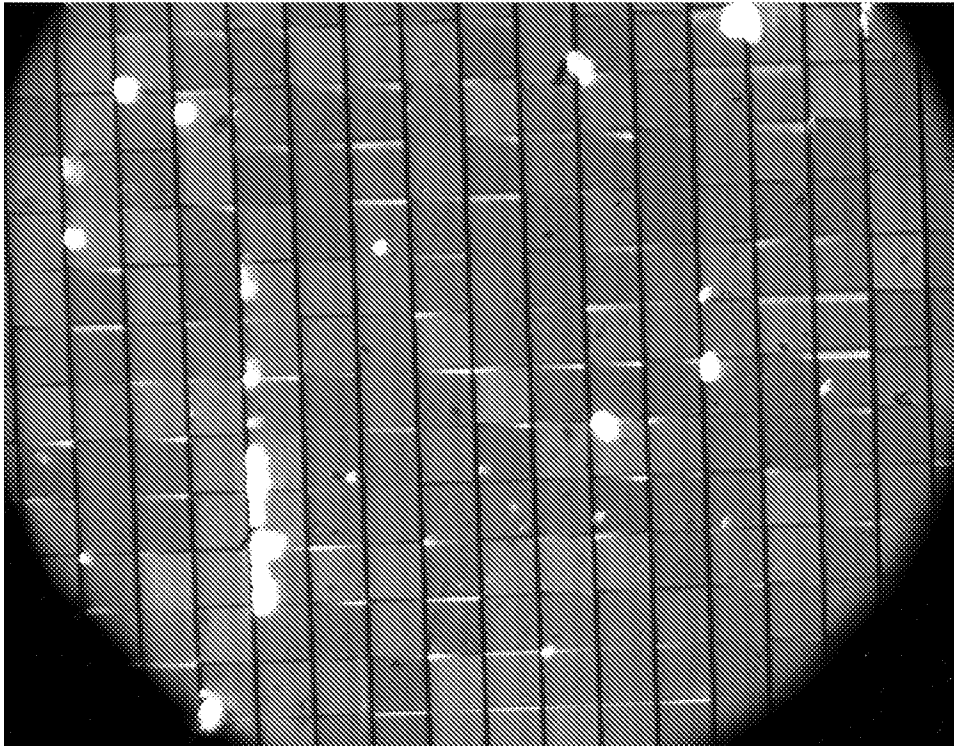
Eye Cross Section

Eye Plot 1

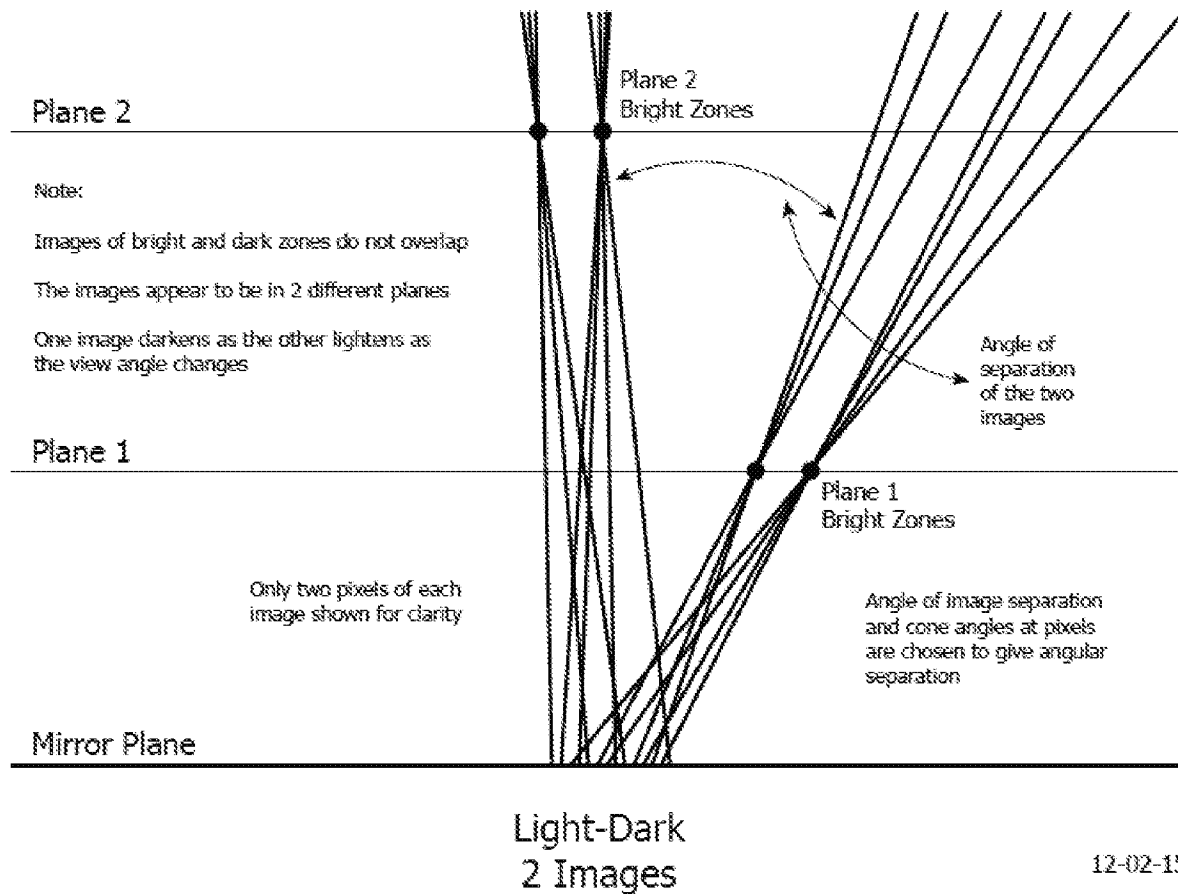
Eye Plot 2

Above is the menu containing ray tracing parameters for ray tracing to a simulated retina.

Below is a microscopic shot of the micro mirrors. The mirrors in this case show the individual angles and are about 50 microns in diameter.



The below image illustrates the concept of the light image (bright pixels with a dark background) going to the reverse, a dark image with a light background as the viewer changes his or her perspective.



Claims

1. The individual mirrors programmed in two axes to focus to a pixel in any visual plane.
2. Micro mirrors used to image pixels forming drawings or text.
3. The ability to use micro-mirrors to focus above or below the visual plane forming pixels or images.
4. The program generating the mirrors, not limited to the algorithms.
5. The shape of the micro mirrors being round, square, rectangular, flat, concave or convex.
6. The size of the mirrors, from about 1000 microns down to one micron.
7. The effects generated from the mirrors, showing images above or below the visual planes.
8. The effect of light images with dark backgrounds animating to light backgrounds and dark images with a change of perspective.
9. The masking effect showing one image receding as it goes across another image
10. The micro mirrors generating more than one level of imagery to the viewer (two or more).
11. The micro mirrors generating one image or pixels at one level above the focal plane.
12. The micro mirrors generating an image below the focal plane.
13. The micro mirrors generating an image at the focal plane.
14. The micro mirrors generating an image per claims 8-13 either with bright pixels (light) or dark pixels (the absence of light or reflected light from the viewer).
15. The micro mirrors providing a combination of any of the above claims.
16. Images created by the micro-mirrors that have an animation effect.
17. Images created by the micro mirrors that have a 3D effect.
18. The technology as used in a currency thread from about 10 microns to 50 microns thick.
19. The technology used as a foil stamp from about 10 microns to about 100 microns thick.
20. Using plasmonic resonance for color, or tinting the reflective mirrors with ink.
21. Using diffraction grating to create color with the micro mirrors.
22. Stamping the micro mirrors into any metallic surface, such as a coin,
23. Using UV or energy cured polymer and then metallizing the mirrors.
24. The effect of seeing the images on two sides of a film using the micro-mirrors.
25. Placing the micro mirrors on glass substrates.
26. Stamping or forming the micro mirrors into surfaces such as chrome or aluminum containers.
27. The micro mirrors used in any high security application, including but not limited to passports and other high security documents including currency.