

Daniel Mitchell

Dr. John Stewart

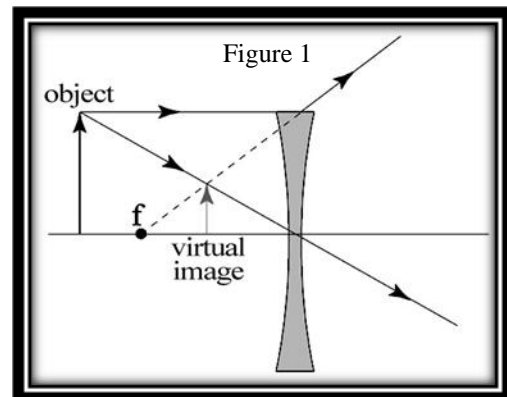
Physics 2074H

April 20, 2009

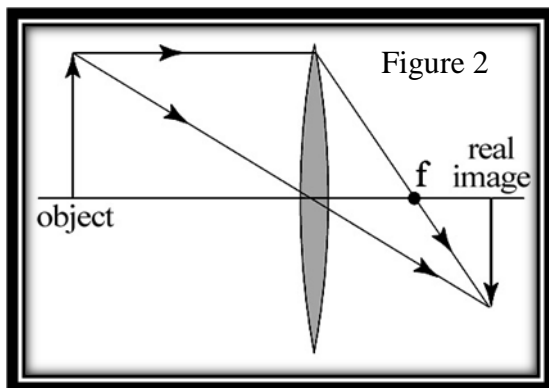
Reflective Holography

There are two types of images, virtual and real, that we observe on a daily basis. In order to describe the differences between the two, you must first understand a few simple aspects of optics regarding lenses and reflective surfaces such as mirrors. An image is the location where all light rays coming from an object meet. With that said, when light rays from an image pass

through or reflect off of a mirror or lens, an image forms at the point in which all of the rays cross or in some cases appear to cross. The latter case describes a virtual image, or one that forms where the light rays appear to cross. Figure 1 represents a virtual image.



As you can see in the figure the rays from the object, represented by solid lines, pass through a concave lens and diverge; however, the virtual image forms where the rays appear to cross. Point f represents the focal point of the lens,

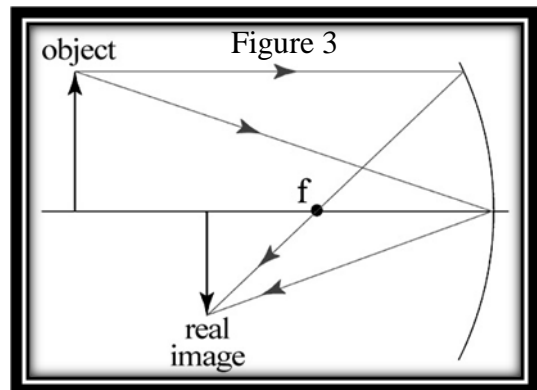


or the point where all of the light rays converge. A simple example of a virtual image is the image you see of yourself upon looking in a mirror. A real image is formed where all of the light rays actually cross. Figure 2 depicts the optics behind a real

image. The light rays pass through the convex lens and converge. The real image appears inverted at the point where all of the light rays intersect.

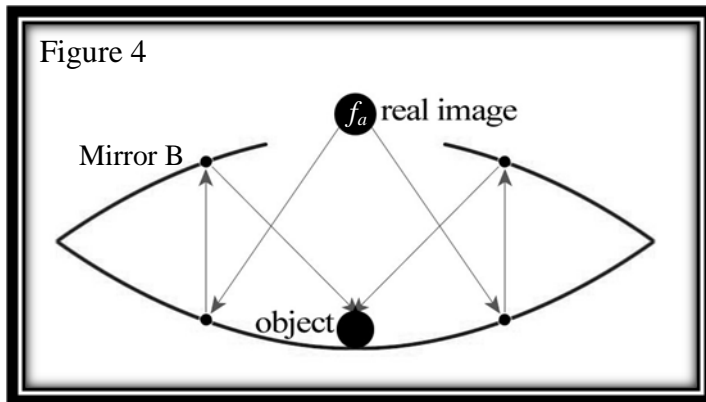
There are several types of holography. Laser holography is the use of coherent light from a laser in order to make a hologram that can then be used to create a three-dimensional image. Reflective holography, the topic of this project, uses only ambient light and parabolic mirrors to produce a real three-dimensional image. Reflective holography has often been used to demonstrate real images in the classroom, but it has also been used as a magic trick because the three-dimensional images it produces appear to look very real.

As stated before, parabolic or concave mirrors produce real images; however, the bowl shape of the mirrors is what allows the image to appear three dimensional, because it can reflect the light rays from all sides of the object. Figure 3



shows how a real image is produced using a single parabolic mirror. When viewing the real image formed by a concave mirror, it appears as a somewhat warped to the center image. The image is also a considerable amount smaller than the actual object that it is reflecting. Aesthetically, there is nothing out of the ordinary or fascinating about the real image that a single parabolic mirror forms; however, if you take two parabolic mirrors that have the same physical properties such as the same focal point and center of curvature, and place them facing each other, the results are captivating. To allow ambient light to enter the system of mirrors, the center of the top mirror must be removed.

Because of the cost and limitations of obtaining such tools to cut a circular hole in the center of a mirror, let alone purchase two concave mirrors to set up the project, I purchased a



Mirage kit, manufactured by Opti-Gone International. The *Mirage* kit includes two parabolic mirrors. One being the base mirror and the other being the top mirror with a circular hole cut out from the center, that fit together so that so

that a three-dimensional real image is produced just above the circular whole. Figure 4 depicts the layout of the two parabolic mirrors, as well as the path light rays travel in order to produce a real image. Notice that the object is actually placed inside of the flying saucer-like shape and the real image is formed directly overhead. The mirrors are designed so that the focal point of Mirror A, shown as f_a in Figure 4, is at the vertex of Mirror B and vice versa. The object located at the vertex of Mirror A is bombarded by light rays which then travel towards the reflective surface of Mirror B. They then reflect off of Mirror B perpendicular to the ground and parallel to one another. The light rays then bounce off of Mirror A at the same angle that they hit Mirror B and converge at f_a , forming a three-dimensional real image.

Below are the dimensions of the *Mirage* kit as well as some calculations:

Mirror diameter:	22.35 cm
Circular hole diameter:	6.35 cm
Height (when stacked):	7.9 cm

The focal length of a mirror is given by the equation $f = \frac{r}{2}$, where r is the distance in centimeters from the center of curvature to the vertex of the mirror. Because I can not accurately calculate the center of curvature, I plugged the dimensions of the mirror into *Parabola*

Calculator Version 1.0. It calculated that my focal length was equal to 7.9 cm or the exact height of my mirrors when stacked. Knowing the focal length, I am now able to calculate the center of curvature, r , by plugging it to the focal length formula.

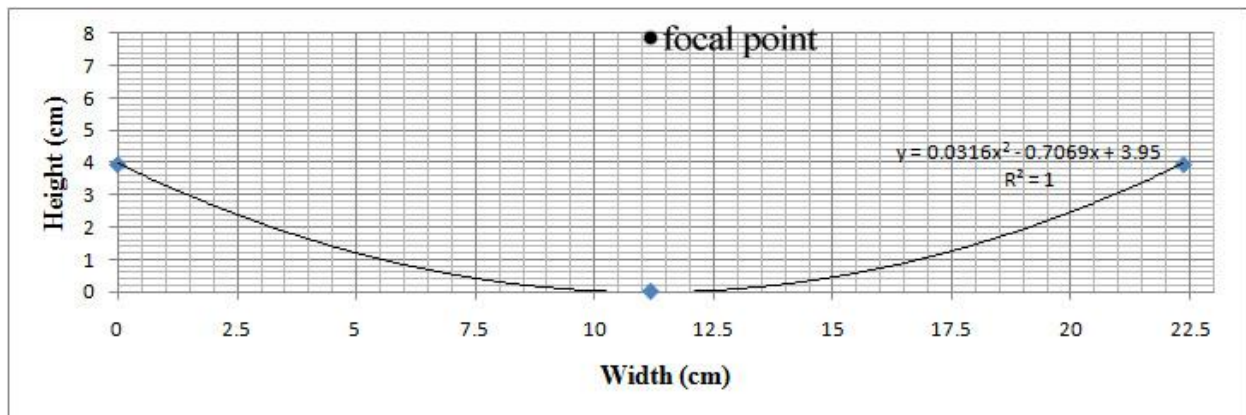
$$\text{Center of curvature: } 7.9\text{cm} = \frac{r}{2}$$

$$r = 15.8 \text{ cm}$$

In order to determine the parabolic equation for the curve of the concave mirror, the radius and height were plotted in Excel on the x-y plane. The data used is shown in Figure 5. After the data was plotted, I then graphed the points and added a parabolic trendline. The equation displayed is not

Figure 5	
x (width)	y (height)
0 cm	3.95 cm
11.175 cm	0 cm
22.35 cm	3.95 cm

entirely accurate; however, it is a rough estimate of the actual equation. The figure below is a graphical representation of the concave mirrors used to project the three-dimensional real image; the focal point is displayed.



The location of the image of the object that appears just above the circular hole corresponds with the calculated focal length. Knowing the focal length and center of curvature of the concave mirrors, what are the effects on the image if the space between the two mirrors increases so that the focal points do not correspond with the opposing mirrors vertex? By holding

the top mirror directly over the bottom mirror and moving it slowly upwards, it is apparent that the image decreases in size, eventually losing its three-dimensional appearance. The three-dimensional real image produced is not an inverted image; however, the image is rotated 180 degrees. The reason that the image is not inverted is simply because the image began inverted, and the second mirror inverted the inverted image, resulting in an upright real image.

Reflective holography can not be appreciated until it is experienced first hand. The three-dimensional images formed by the two concave mirrors are convincing enough to provoke dumbfounded responses when a person reaches for the floating image. It is now being used in many classrooms and museums to show the captivating aspects of optics.

References

- Mirage® 3-D Instant Hologram maker, three-dimensional real image, holograms, parabolic mirror. 20 Apr. 2009 <<http://www.optigone.com/applications/MiragePhysicstext.pdf>>.
- "Physics Demonstrations at Saint Mary's University." SMU Astronomy and Physics. 20 Apr. 2009 <http://www.ap.smu.ca/demos/navigation/navigation_frames.html>.
- "Real image -." Wikipedia, the free encyclopedia. 20 Apr. 2009 <http://en.wikipedia.org/wiki/Real_image>.
- "Virtual image -." Wikipedia, the free encyclopedia. 20 Apr. 2009 <http://en.wikipedia.org/wiki/Virtual_image>.
- "Parabola Calculator." 20 Apr. 2009 <<http://mscir.tripod.com/parabola/>>.