WAVEFRONT ABERROMETRY

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By now, you know quite a bit about the human eye and how it functions, as well as some information about vision defects such as nearsightedness and farsightedness. During this activity, we will explore some ways in which we can diagnose vision defects. However, let's begin with a quick review of the human eye and the features of our model.

The Model of the Eye

? In front of you is the same equipment that we used in previously to model the human eye. What features of the model do you recognize?

? How does one account for nearsightedness and farsightedness in this model?

? What about the accommodating lens? How does it work in this model?

As you may remember from last time, the model we are using includes an adjustable lens, and a screen that represents the retina of the eye.

In order to model nearsightedness and farsightedness, we can simply adjust the distance between the lens and the retina: a nearsighted eye has a retina that is farther than average from the lens, while a farsighted eye is modeled by a retina that is closer to the lens.

Accommodation is the ability of the eye's lens to change in order to focus on objects at a range of distances away – this can be achieved using the syringe on our lens in order to change the radius of curvature of the lens.

Vision Diagnosis

As you already know, most of us have or will have some vision problems. It is important to understand not only what these problems are, but the ways in which they can be diagnosed.

? Here is a picture of a typical eye chart that is used at a doctor's office. How does an eye doctor use a vision chart like this one to diagnoses vision defects?

? What are the advantages of a system like this one?

? What are the disadvantages of a system like this one?

? Have you ever tried to squint to see one of the letters (or anything else) better? What does squinting do to help us? Why does it help?

As you probably know from experience, the eye chart is frequently used to diagnose vision defects. By placing the chart a certain distance away and asking the patient to carefully read the letters, an eye doctor (and ophthalmologist or optometrist) can begin to determine what vision defects you have and begin to determine the level of severity.

However, this diagnosis method depends on the patient's ability to read the chart, and to do so as directed by the doctor. If the patient squints or guesses letters they can't quite see, they may not get a perfect diagnosis – for that reason, the eye chart can be considered a *subjective* diagnostic too – the results depend to some extent on the person being tested.

Modeling the Aberrometers

Now let's look at a new instrument that's being used for vision diagnosis: it is called an aberrometer – it measures the aberrations (or differences from the normal) in our eyes. Aberrations are like defects, and they can occur in any part of our vision system.

♦ We will make a model of an aberrometer by using the eye model we've been using. In the real aberrometer, a light source comes into your eye, reflects off the retina, and comes back out through the front of the eye. This would be rather hard to imitate, so we'll make it simpler: take the small flashlight and clip it to the "retina" so that it points out through the front of the eye. Next, we need a screen so that we can see the light – put up the grid paper screen so that it's just in front of the eye. Lastly, there is an array of small lenses that is the essence of the aberrometer.

? You have a lens array sitting right in front of you – one of the lenses is loose – take it out and look at it. What kind of lens is it? How do you know?

? What does that type of lens do with the light?

The lens you have is a convex lens, also called a converging lens because it converges the light to a point.

♦? Now place the array in the slot in front of the eye – what do you see on the screen?

? Why do you see it?

The grid pattern that you described above is caused by light from the eye lens projected onto the array of lenses – each of those lenses in turn creates a point of light on the screen. This grid pattern is where we will focus our attention for the rest of this activity.

Nearsightedness and Farsightedness

♦? Right now, the eyeball is set up in such a way that there are no aberrations (defects) in the eye or its components. What do you think would happen if, instead of a perfectly shaped eye, we had an eye that was either longer or shorter than normal? What would happen to our grid pattern, and **why**? (Hint – what is happening to the light?)

♦? Go ahead and try it out. Change the shape of the eye (while keeping the flashlight aimed at the lens), and see what happens to the grid pattern. What changes are happening? Why? (If the results do not agree with what you predicted above, discuss it with your instructor.)

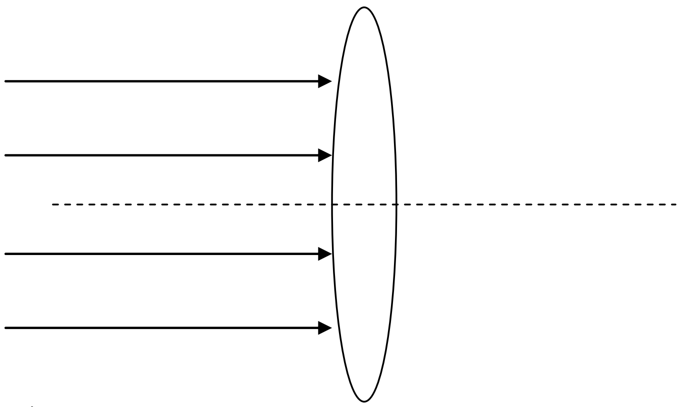
As you saw, when the eye is either nearsighted or farsighted, the spacing of the grid pattern changed. This is because the retina (the location of the light source) is either closer or farther from the lens, which changes the way the light enters the lens and in turn changes the location of the focal points of light.

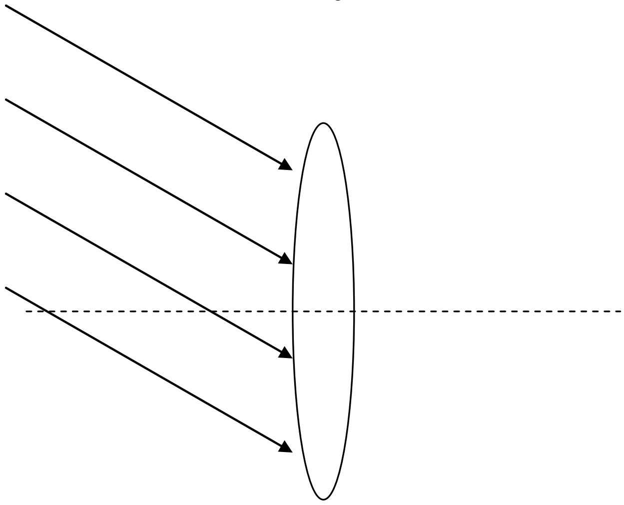
Aberrations in the Lens

♦? Now make sure the eye is back to a normal shape. This time, predict what you think would happen if the lens of the eye had an aberration – if it was not as well shaped as it is right now. What do you think would happen to the grid pattern, and **why**?

♦? Try it – the lens is flexible, so just reach in and push on it lightly. What do you see happening? Why? Does it correspond to what you predicted above?

? Below are two lenses (both are identical), with light rays entering as shown. Please draw the light rays on the other side, after they passed through the lens. If they make a focal point, mark it with a dot.





As you saw above, an aberration in the lens of the eye causes the shape of the grid pattern to be deformed. In this situation, only part of the lens has a defect, and therefore only part of the light is projected differently.

In the ray-diagram activity above, you should have realized that in the first case, the converging lens focuses the light to a single point at a location on the optical axis. In the second case, however, all the light rays are falling on the lens at an angle. Because it is a converging lens it will still form a single point of light, but that point will be shifted – in this case, it will be below the axis (if all the light rays were directed upward and hitting the lens, the point would be shifted above the axis). It is this shift of position of the focal point that causes the grid pattern image to be distorted by aberrations.

♦? Now let's look at a computer simulation that shows you a little bit more about the aberrometer. It's called the "Shack" program – load it up, and switch to English. The white diamonds allow you to change the eye. Move both of them – one allows you to change the length of the eye, and the other allows you to deform the front of the eye. Does this simulation correspond to what you saw with the model? How are the model and the simulation similar?

? How do you think that a doctor could use a system like this aberrometer to diagnose vision defects, both near/farsightedness and aberrations?

? What do you think are some advantages of using a system like this one?

? What about any disadvantages of using a system like this one?

Conclusion

The model that we have created actually functions quite like a real aberrometer. The "screen" of the aberrometer is actually a highly sensitive detector that can measure the properties of the grid pattern – it measures position, intensity, size, etc of the dots of light – the very things you saw changing with the defects. That information is then recorded and, through the use of mathematical algorithms, a computer program transforms that data into what looks like a map of the defects of your eye. One example of the aberrometer output can be seen in Figure .

A doctor can use this system to very accurately and precisely identify the defects in your eye, and as such it is frequently used in conjunction with laser eye surgery techniques. This system allows for the identification of not only nearsightedness and farsightedness, but also aberrations, astigmatisms, and combinations of defects. The aberrometer has the added advantage of being an *objective* diagnosis method because the patient can in no way affect the results of this test. For all these reasons, the aberrometer is quickly gaining popularity and becoming a widely-used diagnostic instrument.

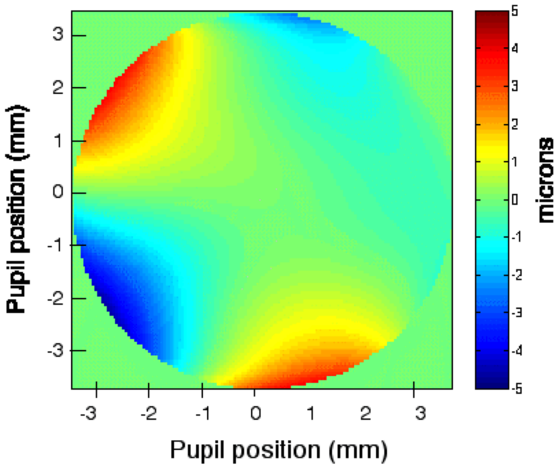


Figure 1 - Sample output of wavefront aberrometer
From http://research.opt.indiana.edu/Library/VSIA/VSIA-2000_taskforce/TOPS4_3.html