GHOST IMAGES

Most of the light striking the front surface of a spectacle lens is transmitted and does what we think it should, i.e. forms a sharp retinal image. Some of the light, however, is reflected off lens surfaces or the cornea to produce spurious or "ghost images". These can be quite disturbing to a minority of patients. We should understand how these images are formed, something about their optical properties, and how to remediate them.

Brightness of Ghost Images

For normally incident light reflected from an air-glass interface with glass of index n, Fresnel's law gives the fraction of reflected light as

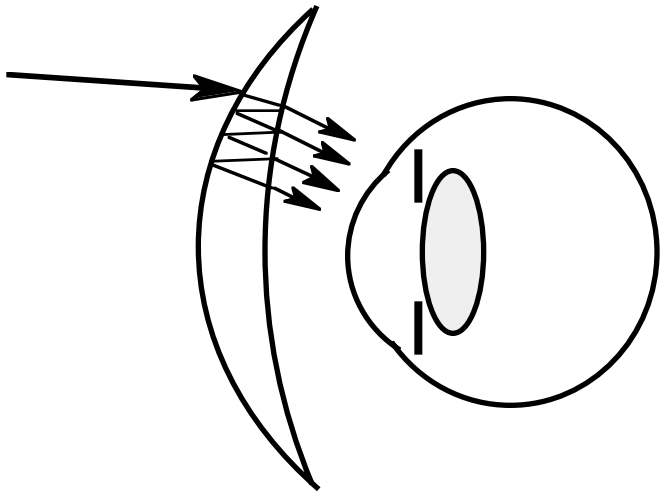
$$\% \text{ light reflected} = 100\% \times [(n-1)/(n+1)]^2.$$

Clinical Significance of Ghost Image

A ghost image is a problem once the patient becomes aware of it. What attributes make him aware of it?

- luminance
- background luminance
- focus
- location in the field
- motion

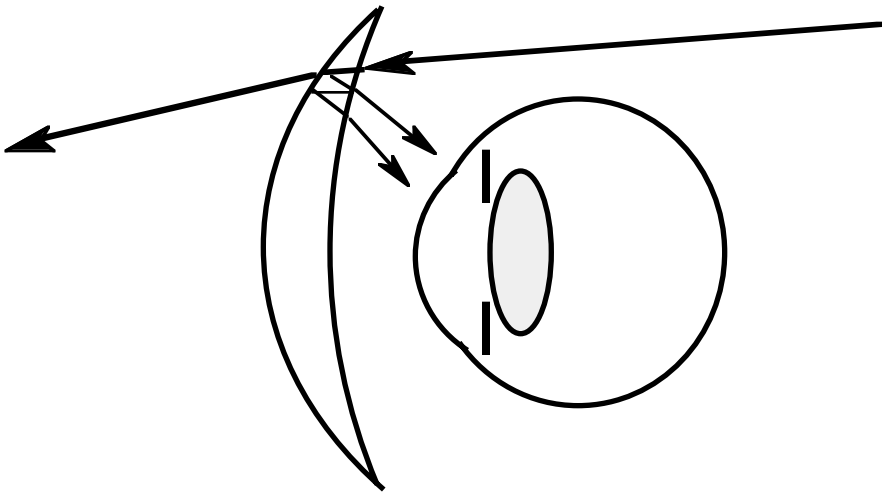
Ghost Images of Sources in front of the Patient



Ghost images of objects in front of the spectacle lens are formed when rays bounce back and forth within the lens or bounce from the cornea to the spectacle lens. These images are dim but can be visible--and annoying--when projected against a dark background. They appear as a ghostly blur, or perhaps several, hovering near a bright light source which moves when the head moves--with motion for myopes, against for hyperopes. The dioptrics of the images can be analyzed using the thick lens formalism. An analysis of the vergence relations gives the following:

- ☞ Images of distant light sources are in focus and hence more apparent for low myopes, less than a diopter.
- ☞ Images of nearer light sources may be focused by low hyperopes. Myopes may sometimes see these images clearly by moving glasses away from the eyes.
- ☞ Other patients will see these images as more or less blurred.

Ghost Images of Sources behind the Patient



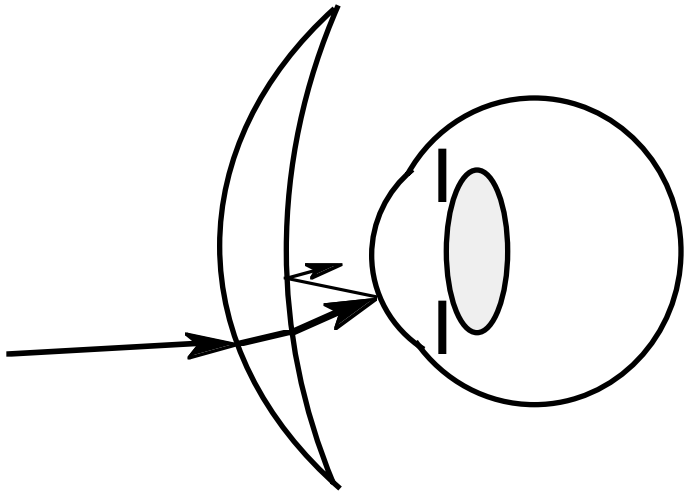
These are images formed by reflection from the back or front surface of the spectacle lens. The patient sees blurred images of distant light sources and, possibly, a sharp view of his own eye and adnexa, hair, spectacles, etc. Since the objects imaged are attached to the patient's head, the images move with head motion. One case can be annoying however. A patient perceives a bright spot temporally, but when he moves his eye to look and see what it is, it vanishes. The cause is vignetting between the pupil of the eye and the spectacle eyewire.

Here are the results of a careful analysis of the vergence relations for these images:

- ☞ No ametrope excepting high myopes can focus images of distant light sources more than a meter behind the lens.
- ☞ Myopes in excess of -8.00DS can see images of objects 1 meter behind them. Patients with lower degrees of ametropia can see much closer objects, e.g. a -4.50D myope sees objects 10cm behind the lens.
- ☞ Objects 5cm behind the lens can be focused by hyperopes or myopes of ametropia greater than 1.00D.
- ☞ Images of the eye and its adnexa 20mm behind spectacles can be focused by myopes in excess of 6.50D and hyperopes in the range 5.00 to 6.50, the higher hyperopes having to employ considerable accommodation.

Other Troublesome Reflections

Images Involving Specular Reflection from the Cornea



The 1st Purkinje image lies about 3.5mm behind the cornea. Using this image as the object, ghost images formed by reflection have dioptric properties similar to those formed by objects behind the head.

Reflections off Segment Tops

Streak reflections may be produced in bifocals by reflection off the segment tops. Patients perceive vertical streaks or bars of light. Vergence of light is that produced by the distance lens, so remote objects give sharp streaks. Streak images are faint, intensity depending on polish of interface. Reflections most intense in one piece bifocals, 3.9% vs. about 0.16% in fused bifocal.

Power Rings

These are the replications seen nasally and temporally reflected in the lenses of high ametropes. They don't bother patient directly, but may be distracting cosmetically. The problem worst in high minus lenses.

Solving the Ghost Image Problem

Here are six techniques for dealing with ghost image problems.

Adjustment of lens and frame parameters.

Adjusting base curve or pantoscopic tilt may move images slightly, but won't get rid of them. Adjustment is ineffective.

Smaller Eye Sizes

This may help slightly with reflections from objects behind the head, but is usually not a practical alternative.

Decentration

The idea here is to move ghost images, especially those formed by objects in front of the patient. It doesn't work.

Changing Base Curve

Changing base curve is completely irrelevant to images of objects infront of the patient and will make only a negligible difference for objects behind.

Contact lenses

This works perfectly optically, but may not be practicle for some patients.

Counseling

This is the commonest and best approach. Once patients understand the origin and inevitability of the ghost image problem, they can usually adapt.

Change bifocal style

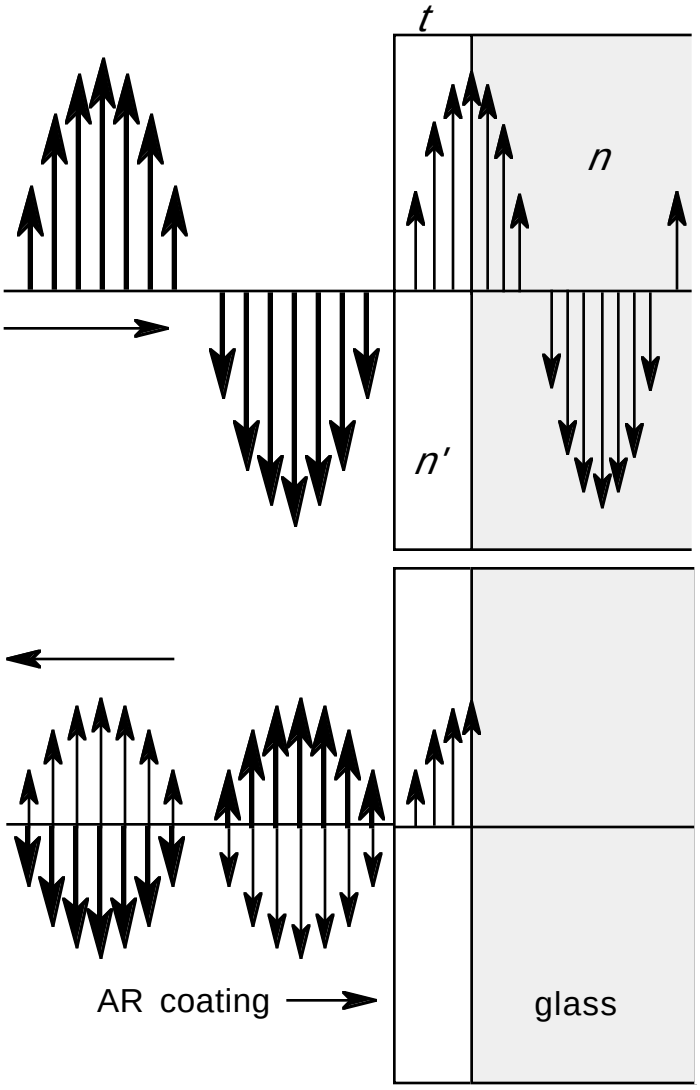
Changing to a fused bifocal or progressive will help with vertical streaks.

Edge treatment

Some edge treatments, e.g. AR coatings, will make power rings harder to see.

Anti-reflective coating

Here thin film on the lens sets up interference between waves reflected from 1st and from 2nd surface of the film, enhancing transmittance.



The figures above shows how an AR coating works. The top figure shows light incident on a lens and its coating. The bottom diagram shows light reflected from the air-coating interface and the coating-glass interface. The coating and its thickness are chosen so the two wavefronts have the same amplitude and are exactly out of phase so the cancel when combined.

The reduction of reflections with a single coating is incomplete but multiple layers can help further to reduce amplitude and to cancel out light at several wavelengths. As many as 9 layers may be used cancelling up to 99.5% of reflected light. Many of these coatings are protective as well.

Finally, complaints about ghost images are relatively rare. Most common offender is the reflection from back and front lens surfaces of a small light source in front of the patient in a dark area, usually with the complaint, "I see extra images of street lights at night." The patient may also complain of seeing double. A careful history can diagnose the complaint, and counseling usually takes care of it. If not, try contacts or and AR coating.

