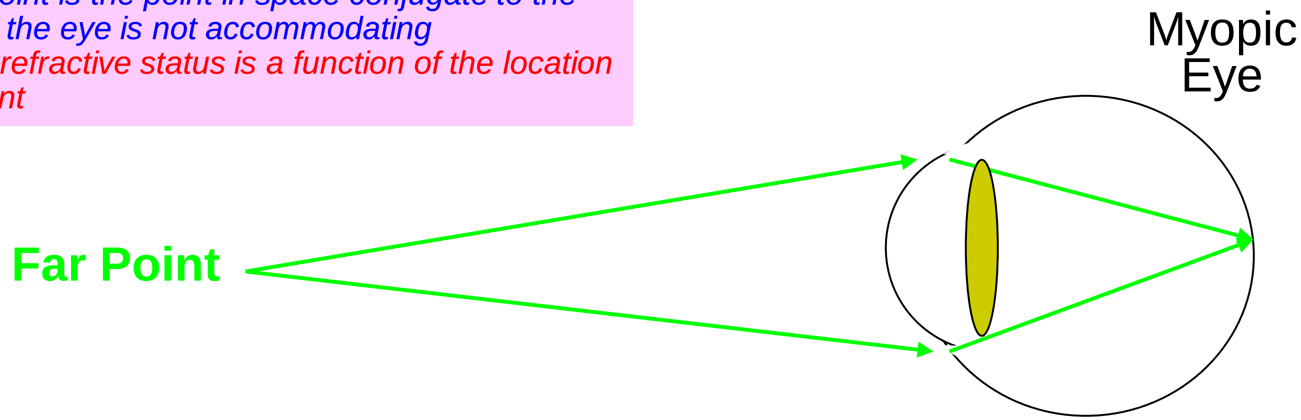
Astigmatic Refractive Error: Introduction

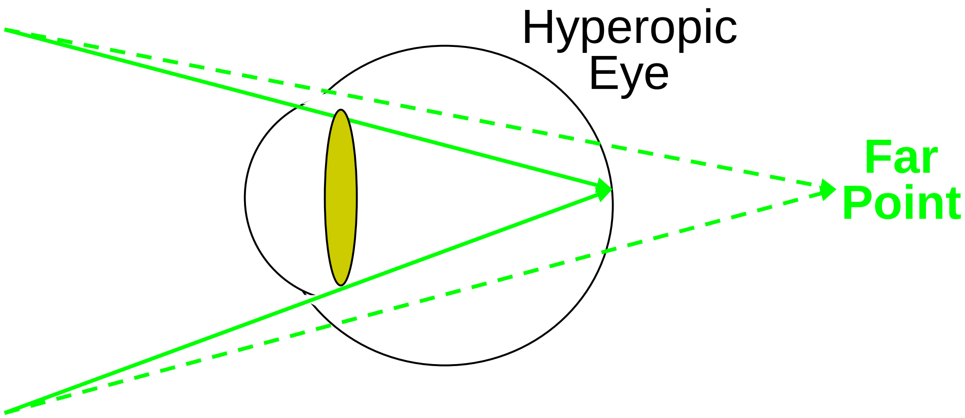
Basic Optics, Chapter 10

Refractive Error and Its Correction: Review

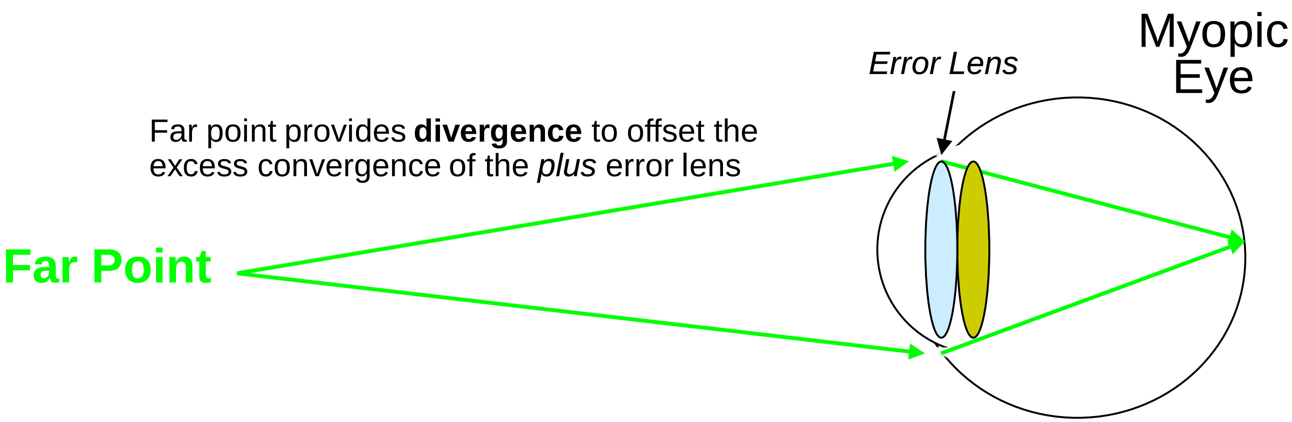
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point



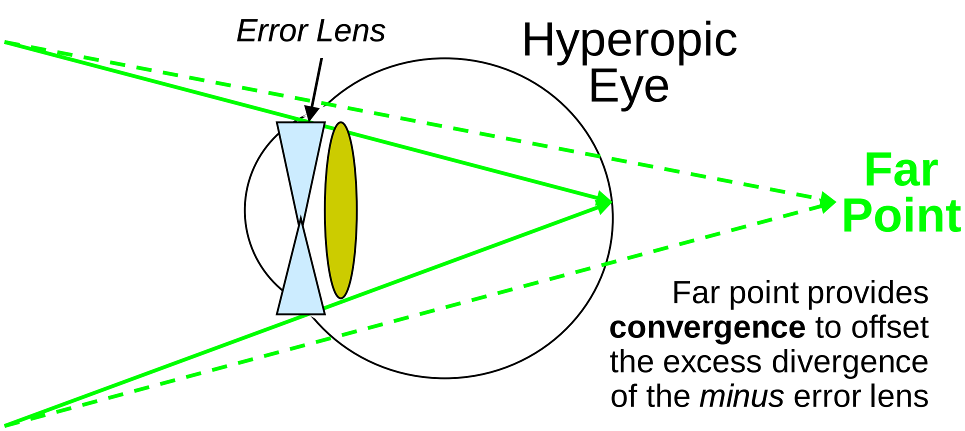
In Chapter 5, we learned that refractive error is fundamentally a ***Far Point*** problem. The far point of the myopic eye is just anterior to the cornea, whereas the far point of the hyperopic eye is behind the eye. Absent correction or accommodation, neither is in focus at distance.



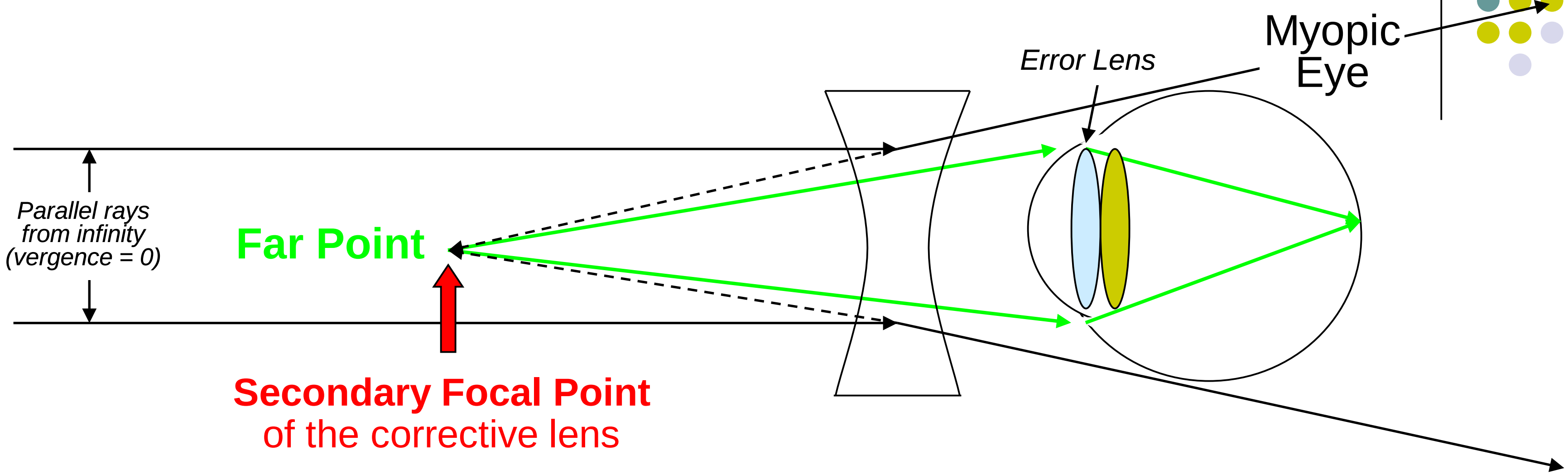
Refractive Error and Its Correction: Review



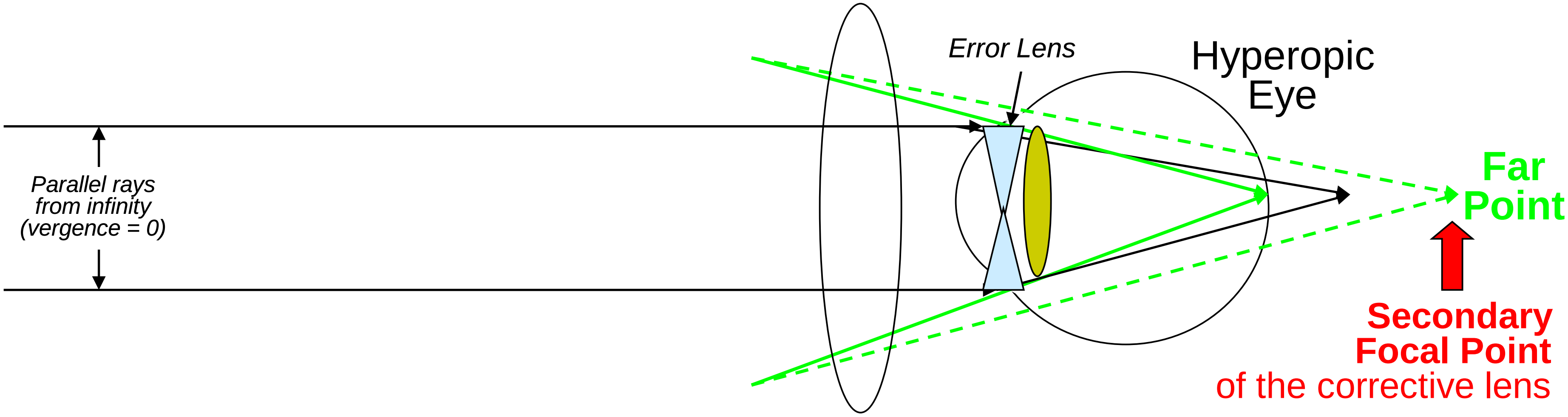
In Chapter 8, we employed the ***Error Lens* concept** to explain why the far point of the myopic and hyperopic eyes are located where they are.



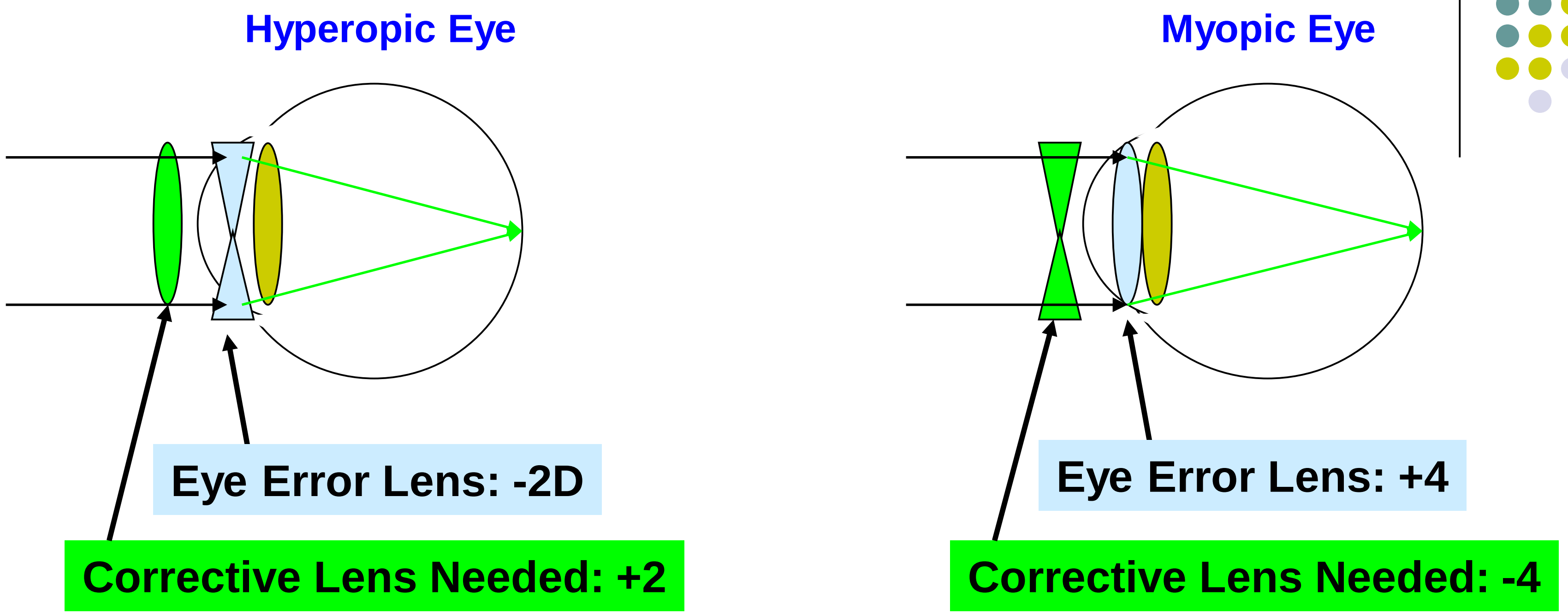
Refractive Error and Its Correction: Review



In Chapter 6, we summarized refraction thusly: *Place a lens in front of an eye so that the* secondary focal point *of the lens coincides with the* far point *of the eye*.



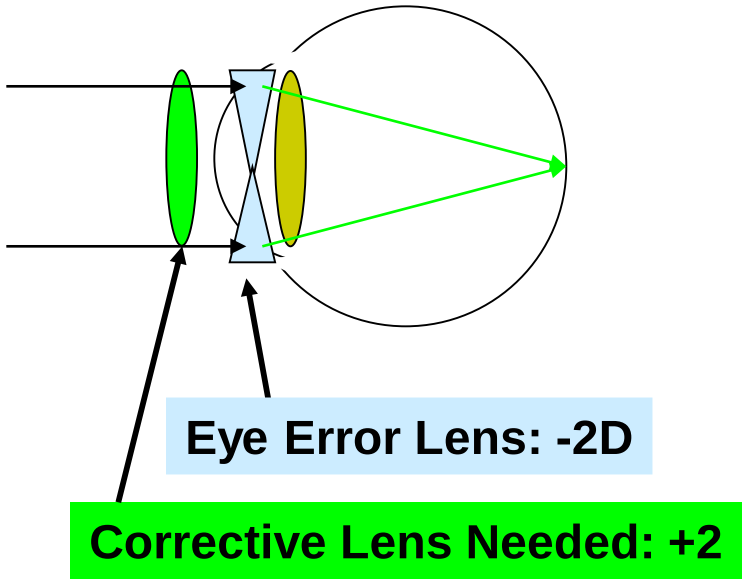
Refractive Error and Its Correction: Review



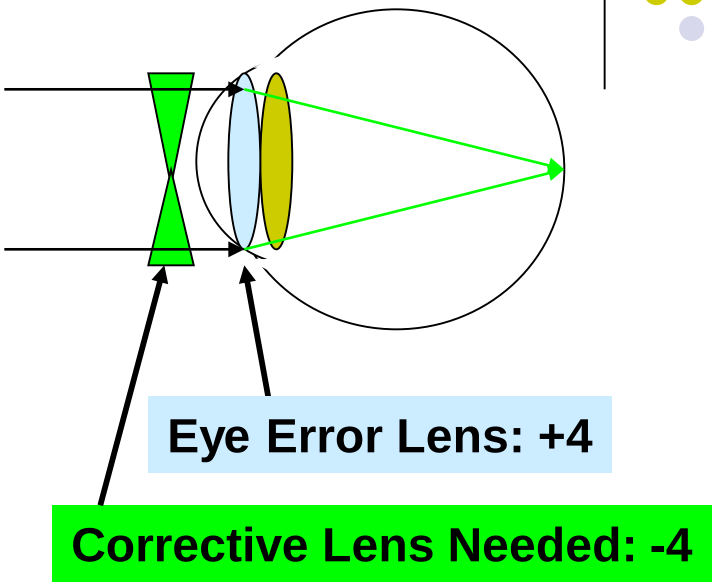
To offset the error lens, the corrective lens needs to be of equal but opposite power (except for the adjustment in power needed to account for vertex distance).

Refractive Error and Its Correction: Review

Hyperopic Eye



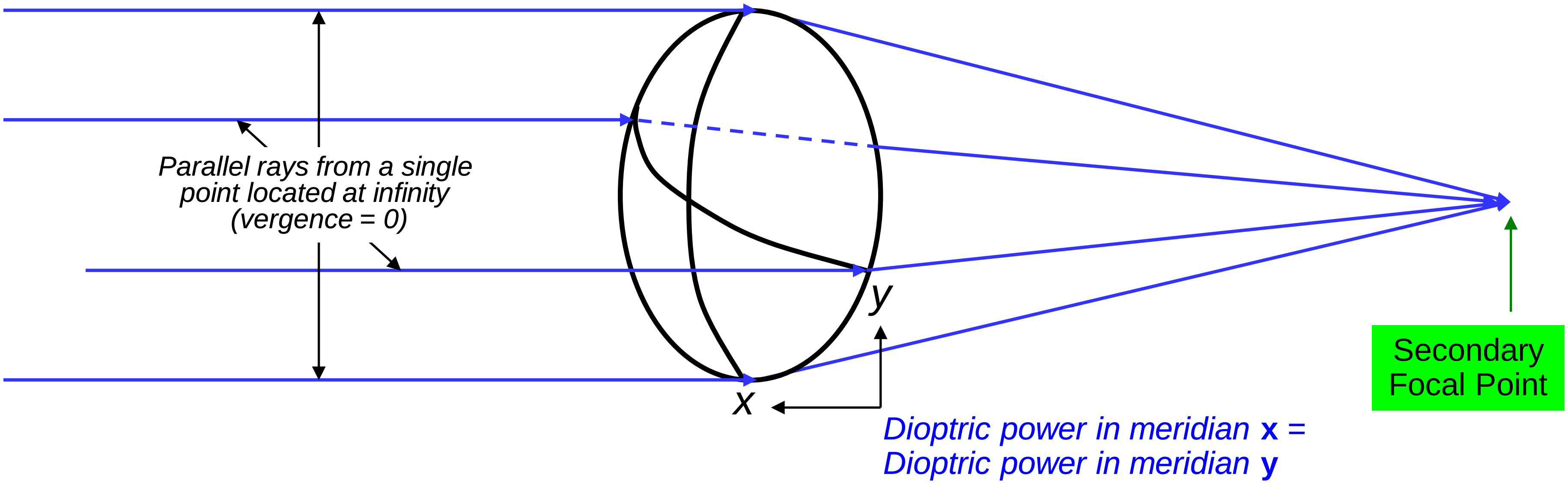
Myopic Eye



To offset the error lens, the corrective lens needs to be of equal but opposite power (except for the adjustment in power needed to account for vertex distance).

But note that the discussion thus far has dealt solely with *spherical* refractive error (and therefore with spherical error lenses).

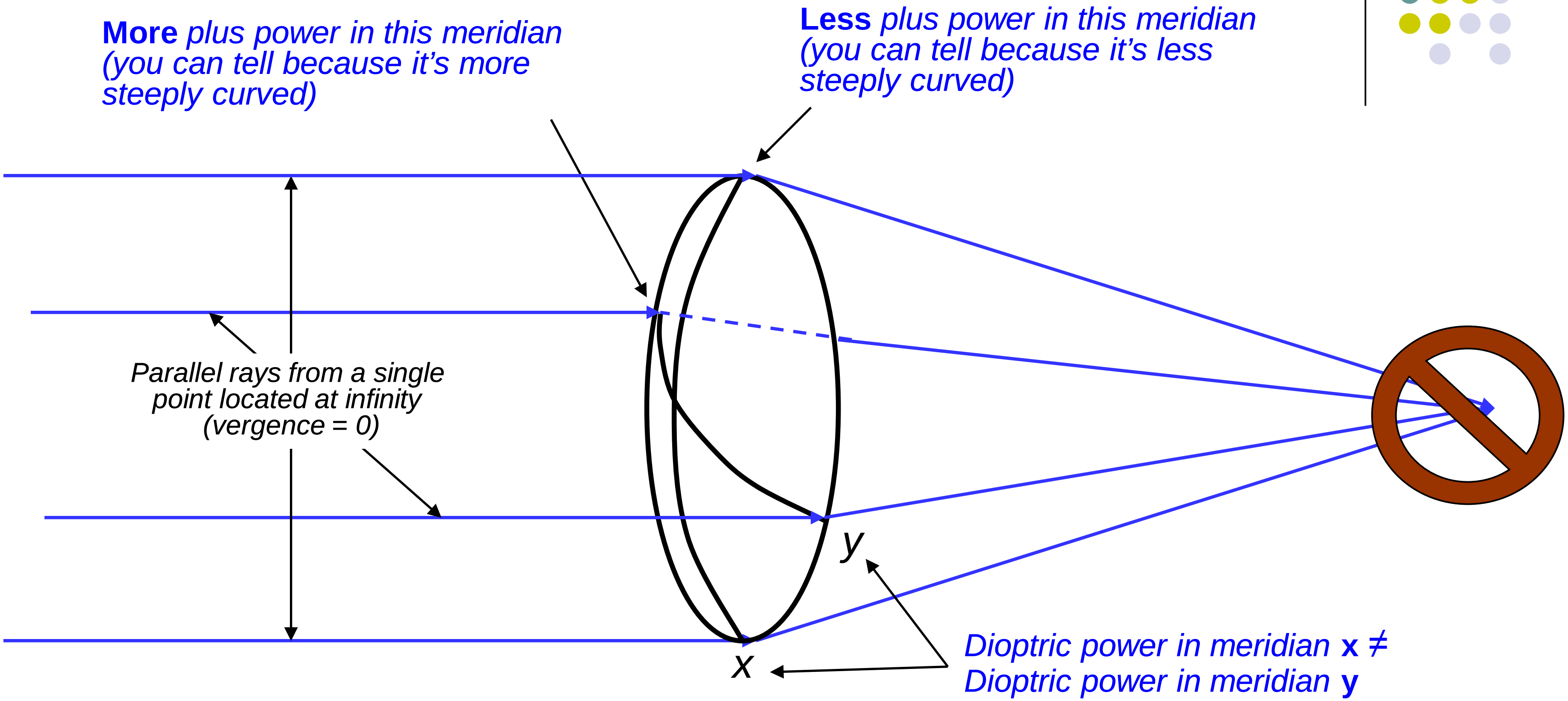
Spherocylindrical Lenses



By definition, a ***spherical*** lens has equal power in all meridia, and focuses parallel rays to a single point at its secondary focal point*

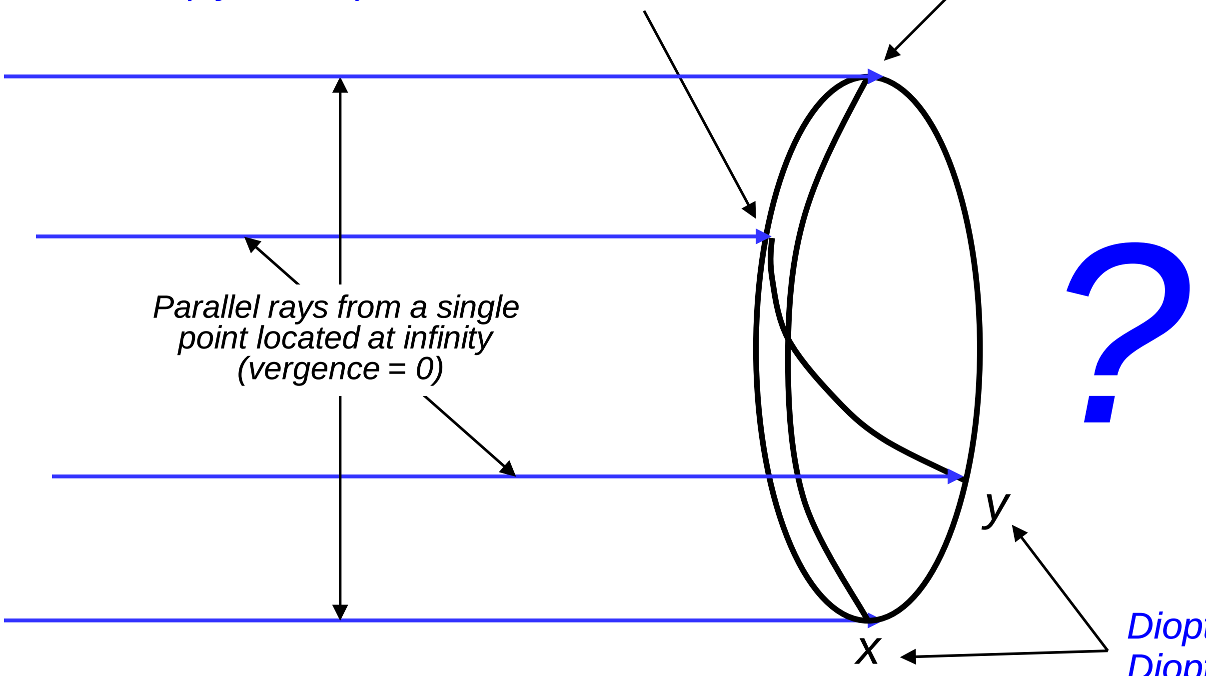
*Bear in mind we are discussing **idealized** lenses here. We will see in a chapter on *Aberrations* that a true point-focus is exceedingly hard to come by!

Spherocylindrical Lenses



In a ***spherocylindrical*** lens, however, the dioptric powers are ***not*** equal in all meridia, so light will ***not*** be focused to a single point!

Spherocylindrical Lenses

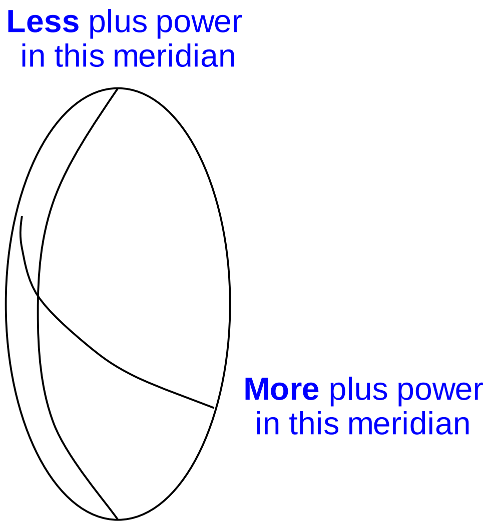


So how does a spherocylindrical lens focus light?

In a ***spherocylindrical*** lens, however, the dioptric powers are ***not*** equal in all meridia, so light will ***not*** be focused to a single point!

Spherocylindrical Lenses

Spherocylindrical lens

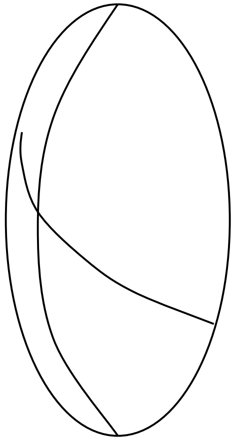


How does a spherocylindrical lens focus light?

To answer this, first consider that a spherocylindrical lens consists, in essence, of two **cylindrical** lenses of differing dioptric powers oriented 90º apart

Spherocylindrical Lenses

Spherocylindrical lens **=** Cylindrical lens **+**



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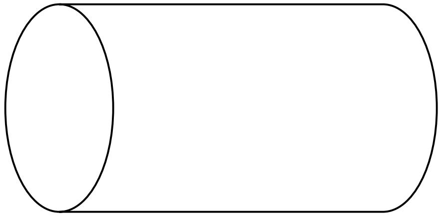

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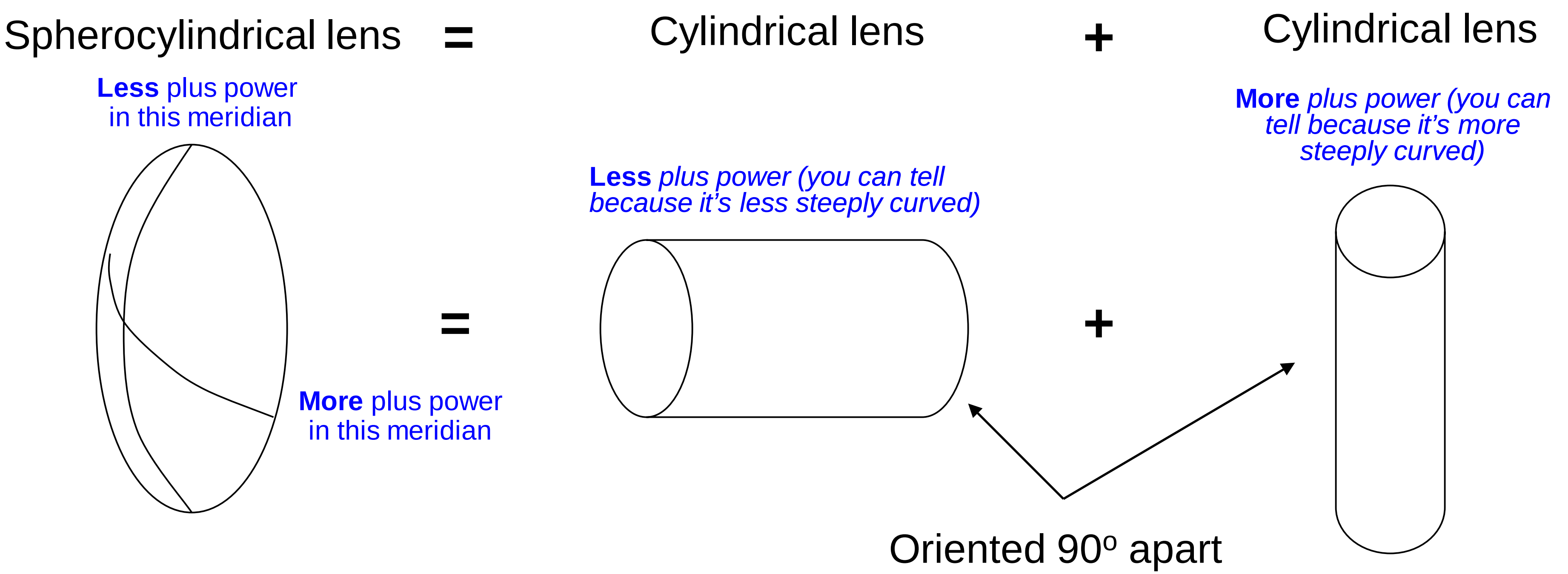
Spherocylindrical Lenses

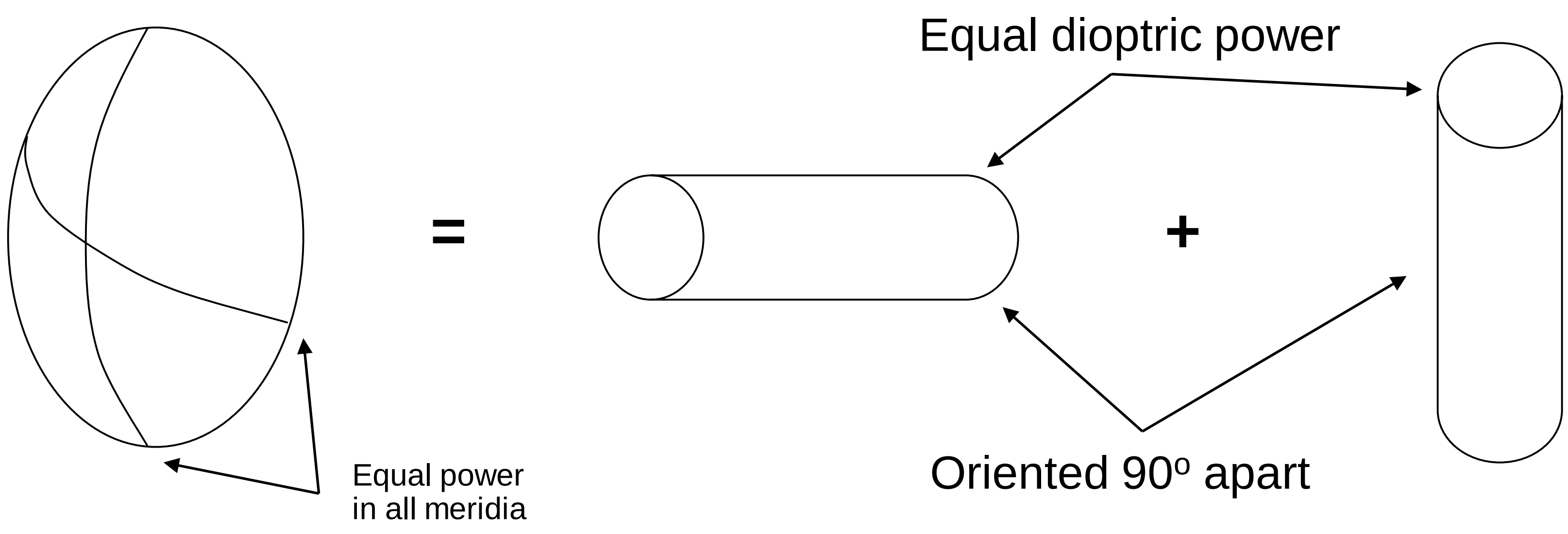


How does a spherocylindrical lens focus light?

To answer this, first consider that a spherocylindrical lens consists, in essence, of two **cylindrical** lenses of differing dioptric powers oriented 90^o apart

Spherocylindrical Lenses

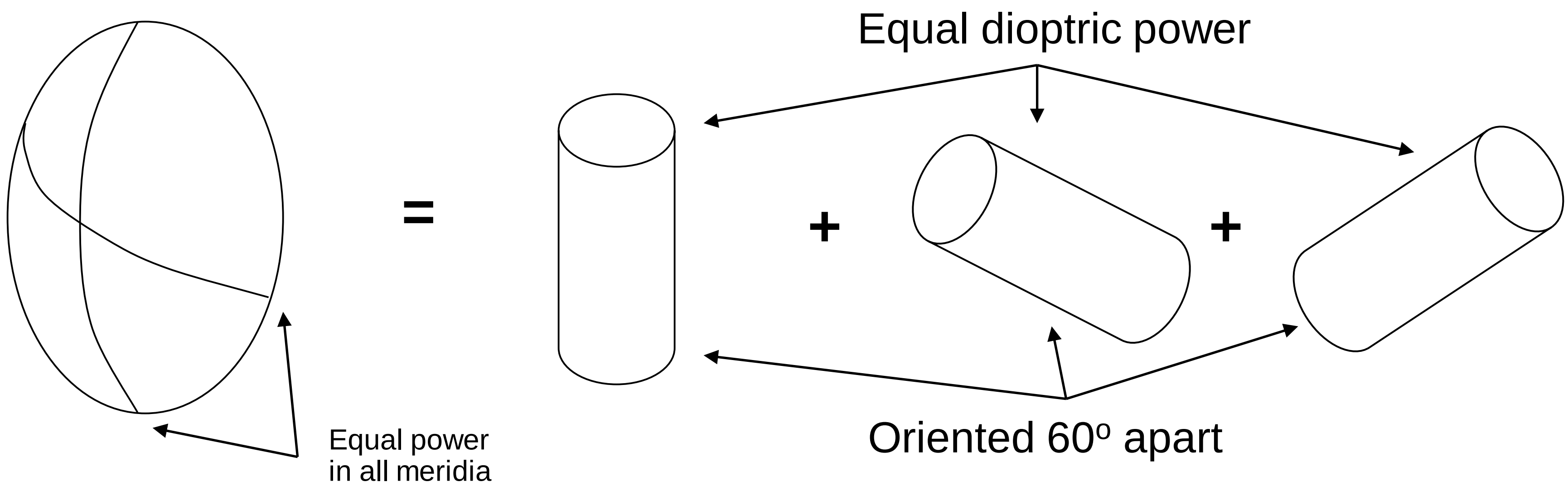
Spherical lens = Cylindrical lens + Cylindrical lens



By the way…A *spherical* lens can be thought of as two cylindrical lenses of *identical* dioptric powers oriented 90º apart…

Spherocylindrical Lenses

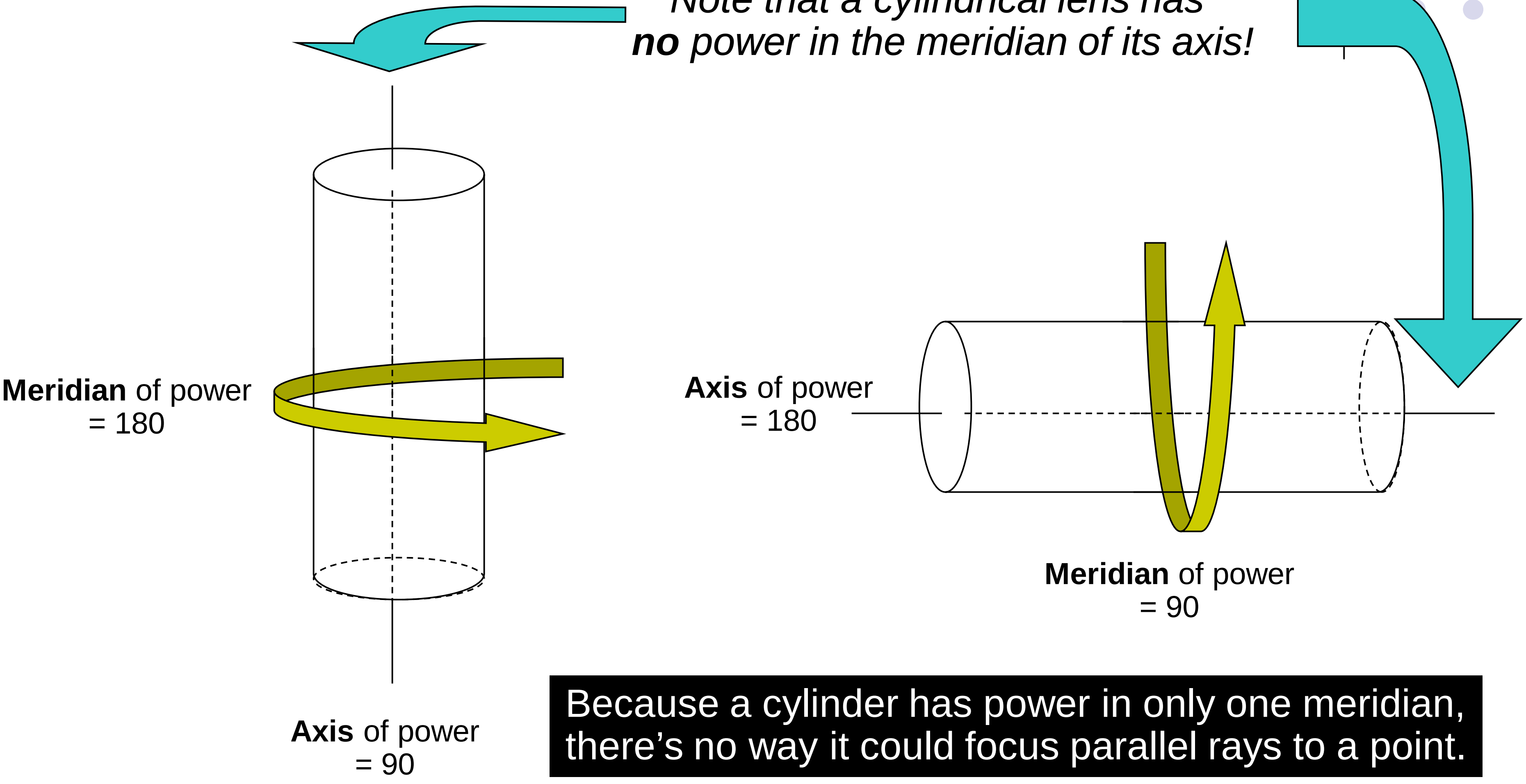
Spherical lens = Cylindrical lens + Cylindrical lens + Cylindrical lens



…or for that matter, as THREE cylindrical lenses of identical power oriented 60º apart, or four at 45º, etc. But for now, just think of it as two identical cylinders at 90º to one another.

Spherocylindrical Lenses

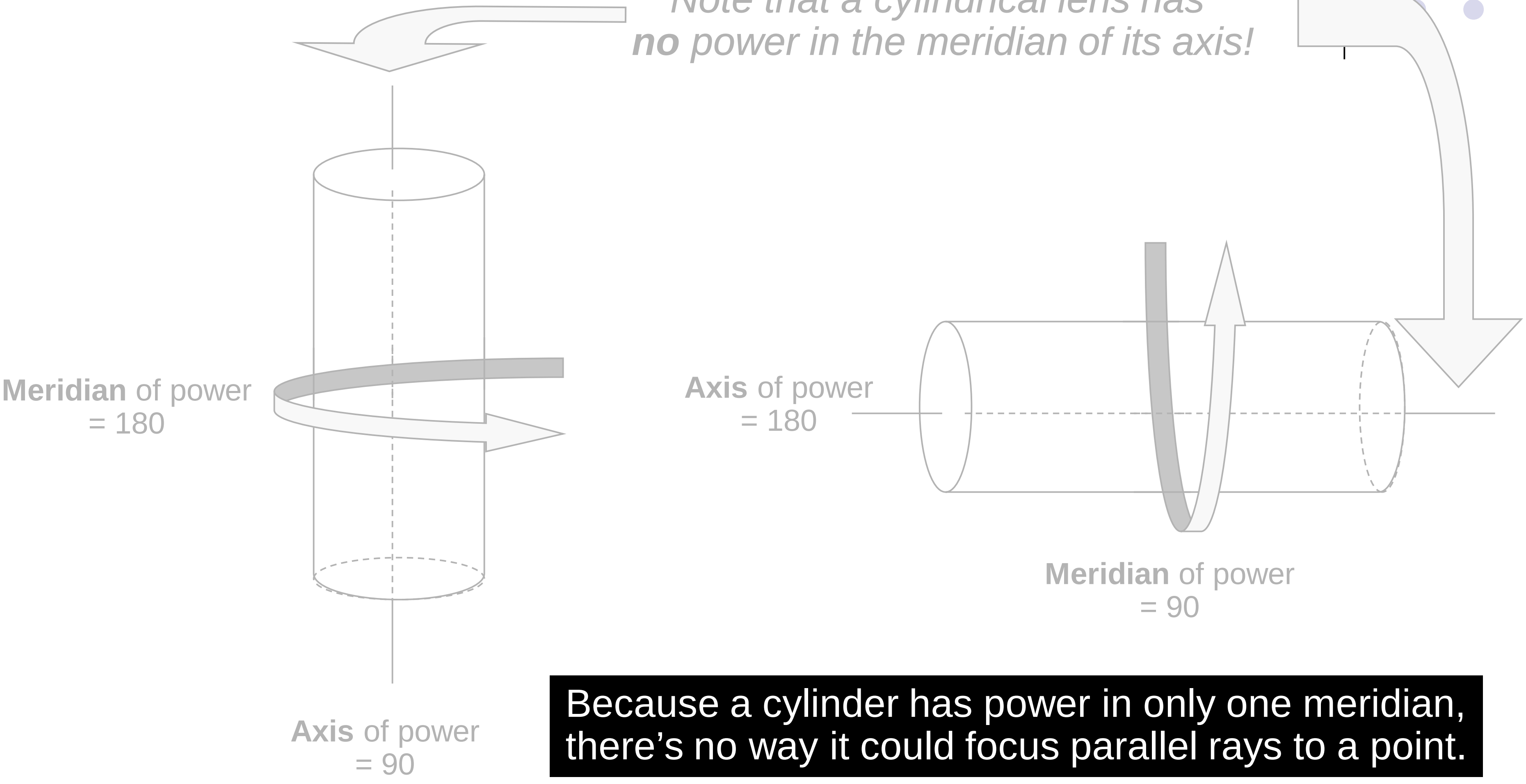
Note that a cylindrical lens has
***no** power in the meridian of its axis!*



Because a cylinder has power in only one meridian, there’s no way it could focus parallel rays to a point.

Spherocylindrical Lenses

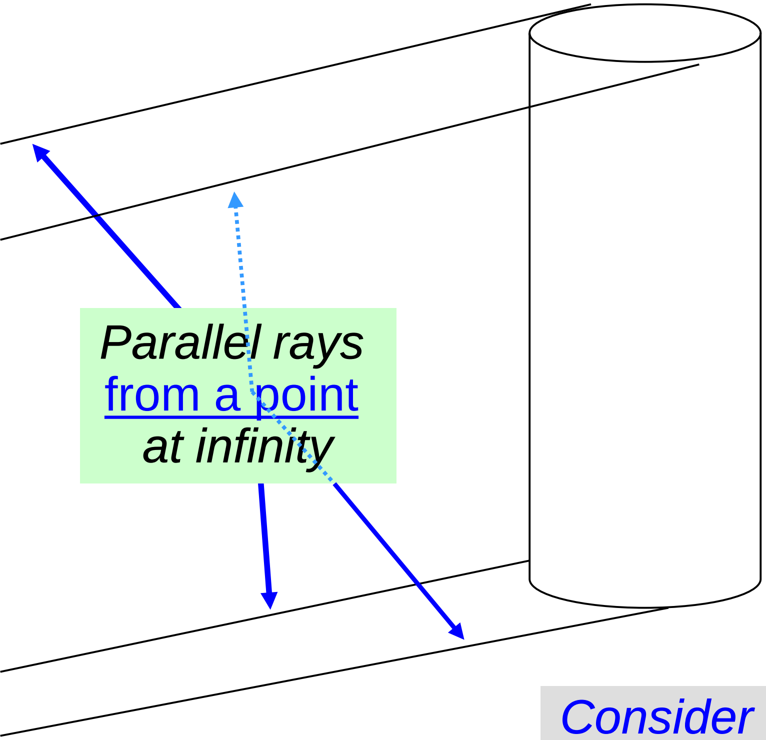
*Note that a cylindrical lens has **no** power in the meridian of its axis!*



Because a cylinder has power in only one meridian, there's no way it could focus parallel rays to a point.

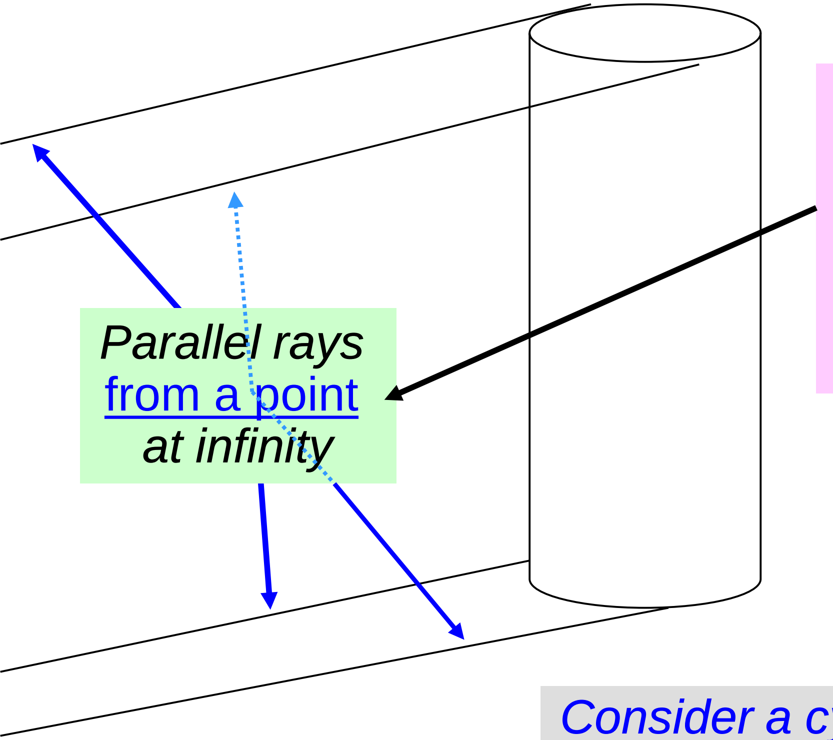
So then, how does a cylinder focus light?

Spherocylindrical Lenses



Consider a cylinder, oriented as shown, that is encountering parallel rays from a point at infinity…

Spherocylindrical Lenses

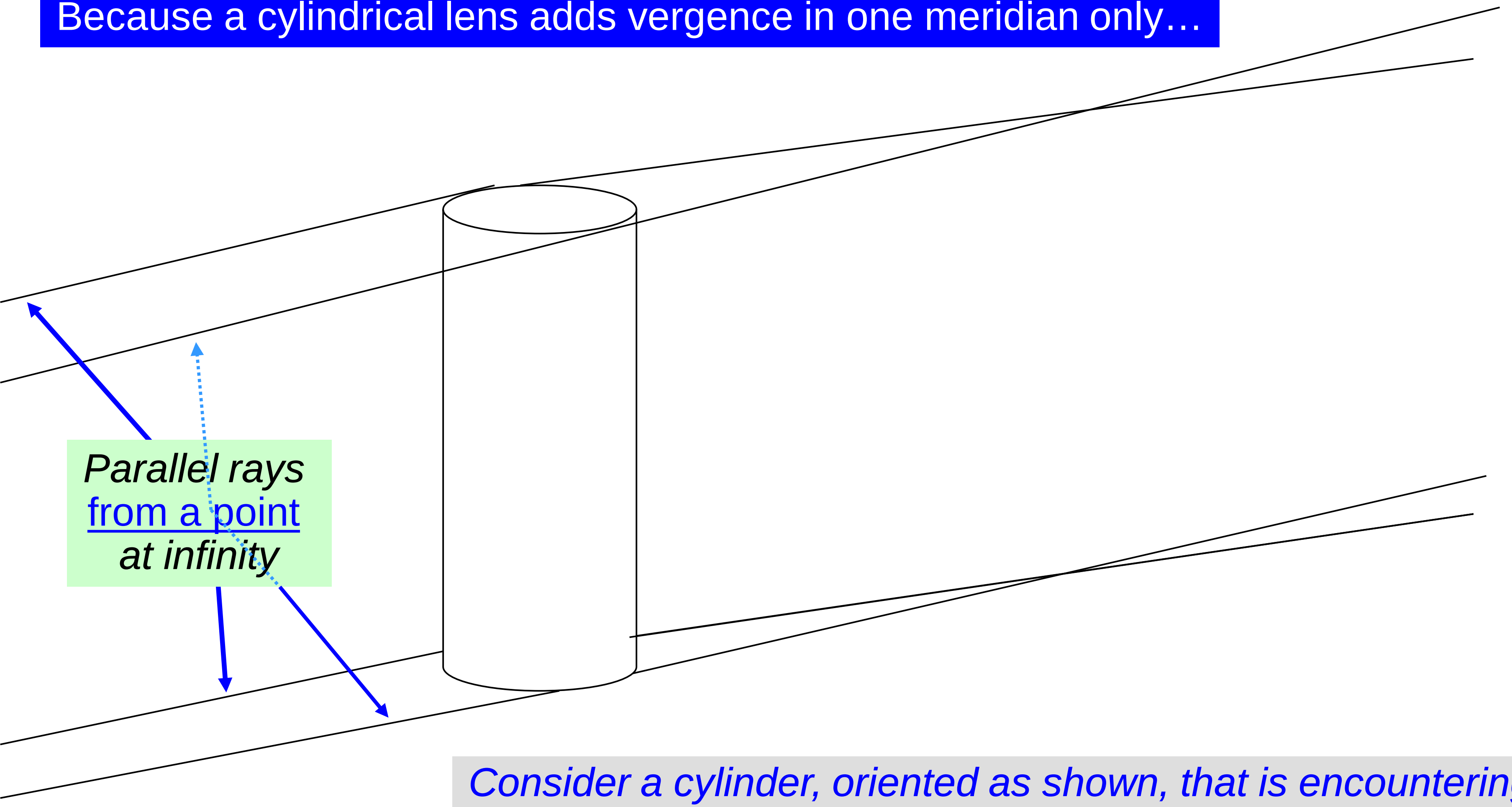


(This is important! The separateness of the rays in the drawing seems to indicate that they originate at different locations on the source of origin. *They do not!* They originated from a single point, but are so far removed from that point that their relative vergence is now zero.)

Consider a cylinder, oriented as shown, that is encountering parallel rays from a point at infinity…

Spherocylindrical Lenses

Because a cylindrical lens adds vergence in one meridian only…



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Spherocylindrical Lenses

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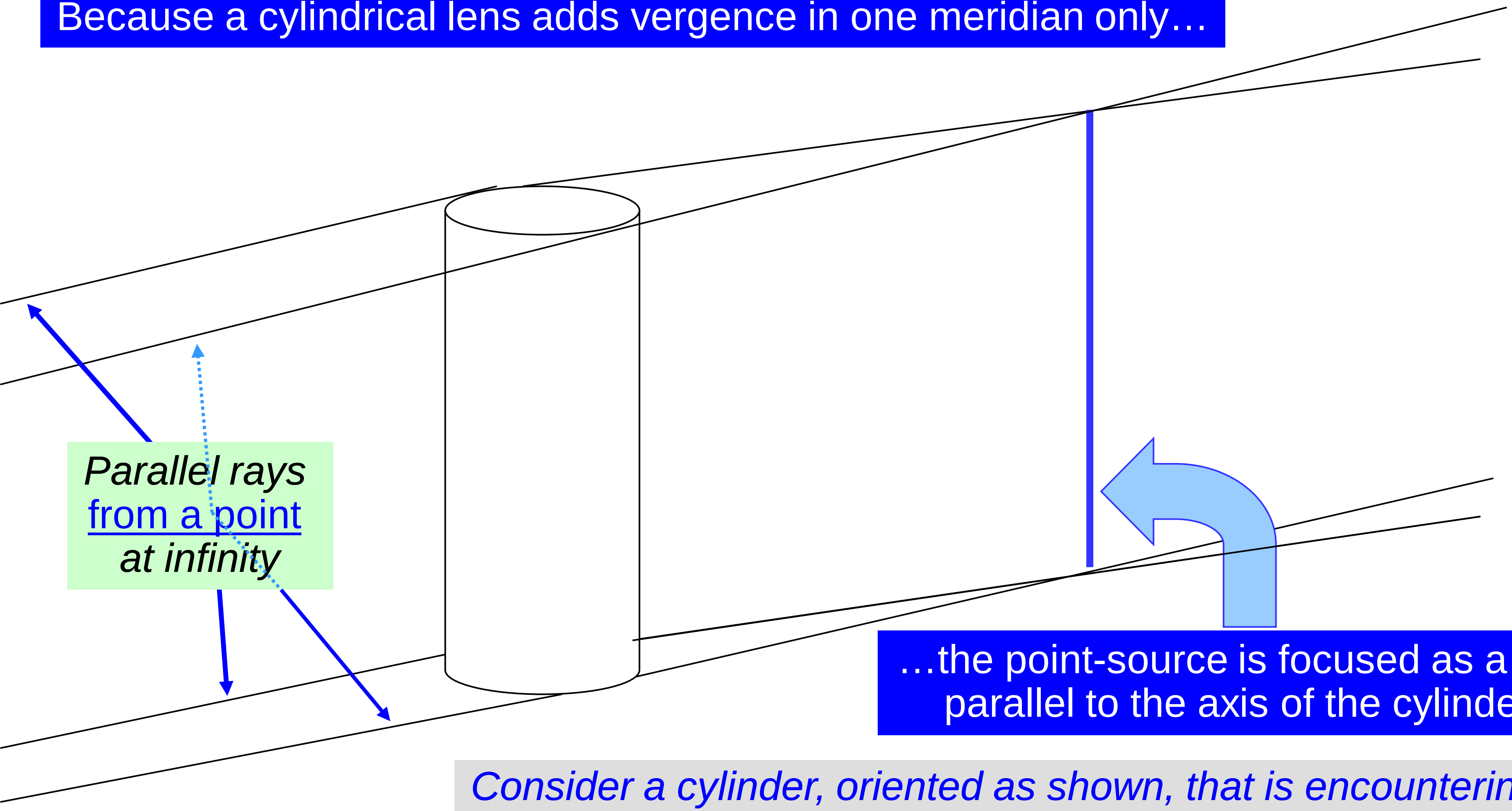
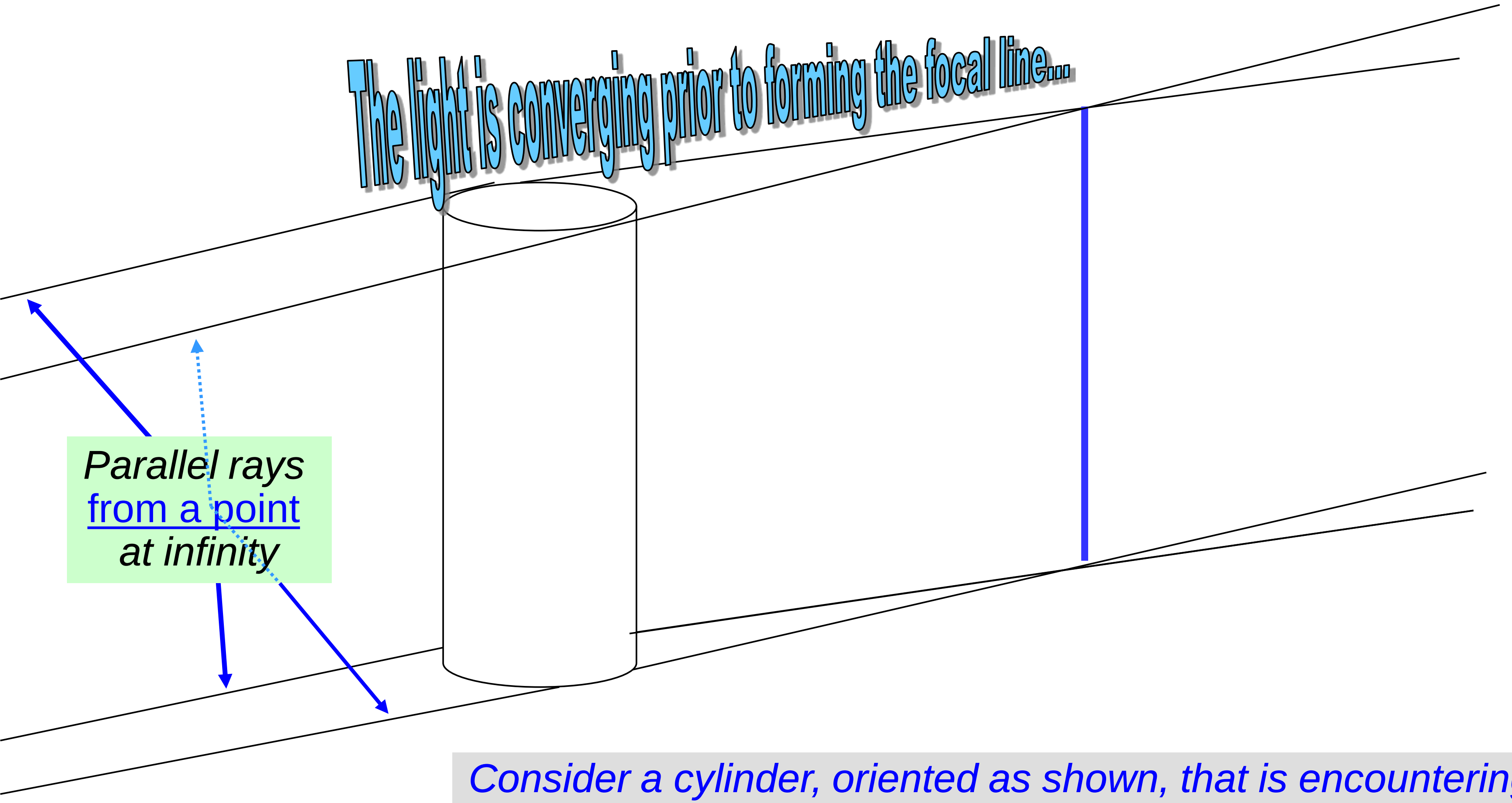


…the point-source is focused as a **line** parallel to the axis of the cylinder.

Consider a cylinder, oriented as shown, that is encountering parallel rays from a point at infinity…

Spherocylindrical Lenses



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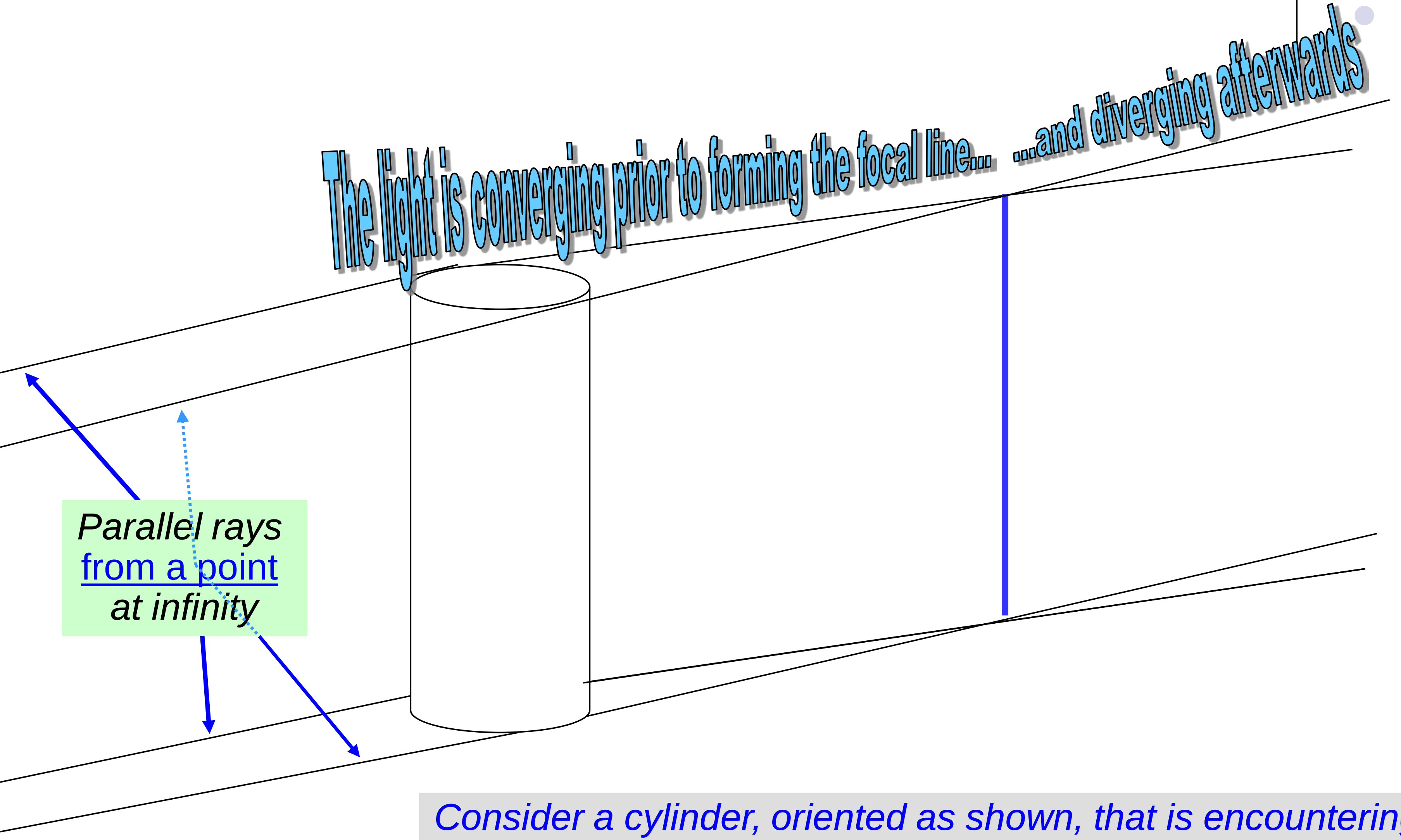
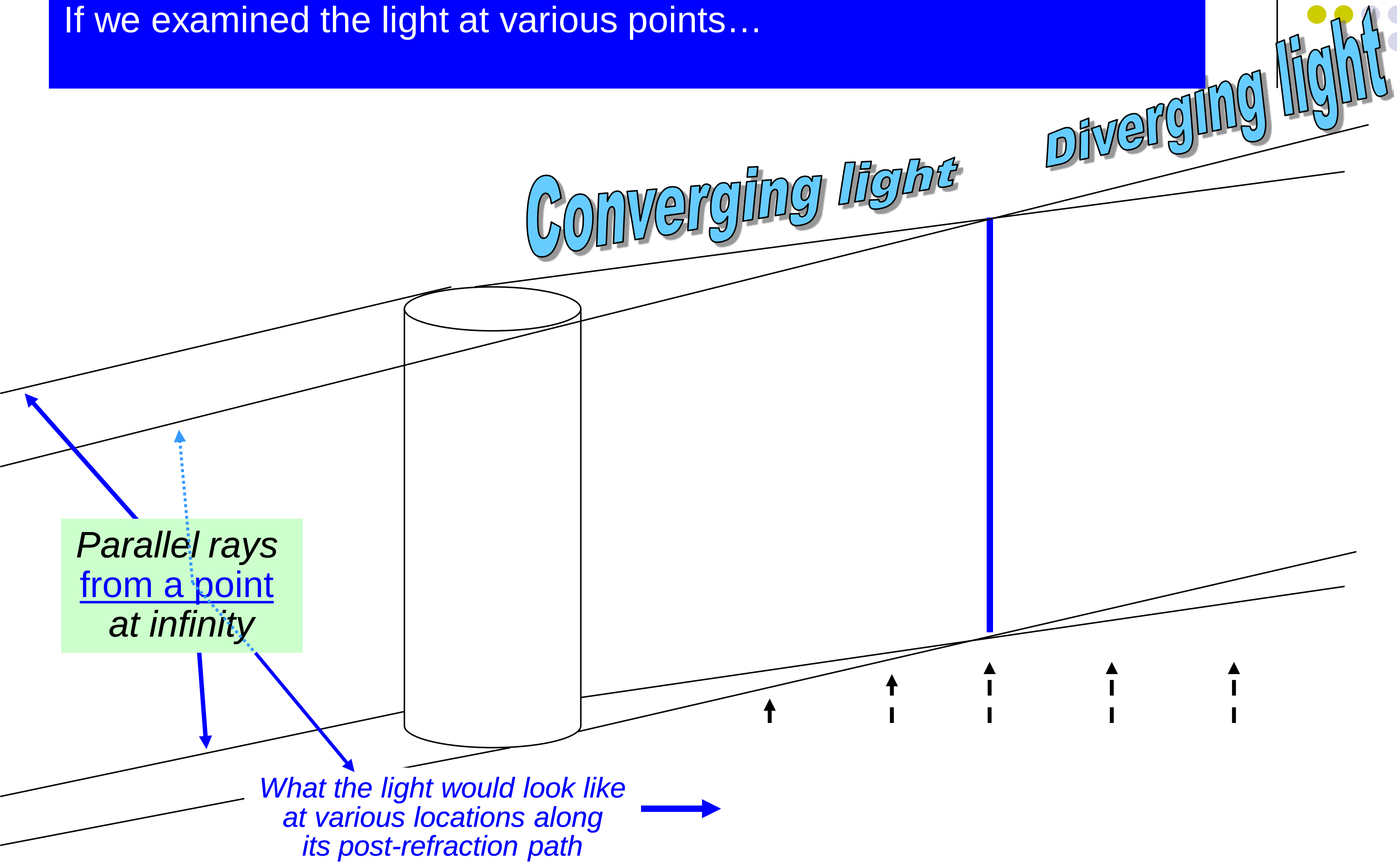
Spherocylindrical Lenses



Consider a cylinder, oriented as shown, that is encountering parallel rays from a point at infinity…

Spherocylindrical Lenses

If we examined the light at various points…



Spherocylindrical Lenses

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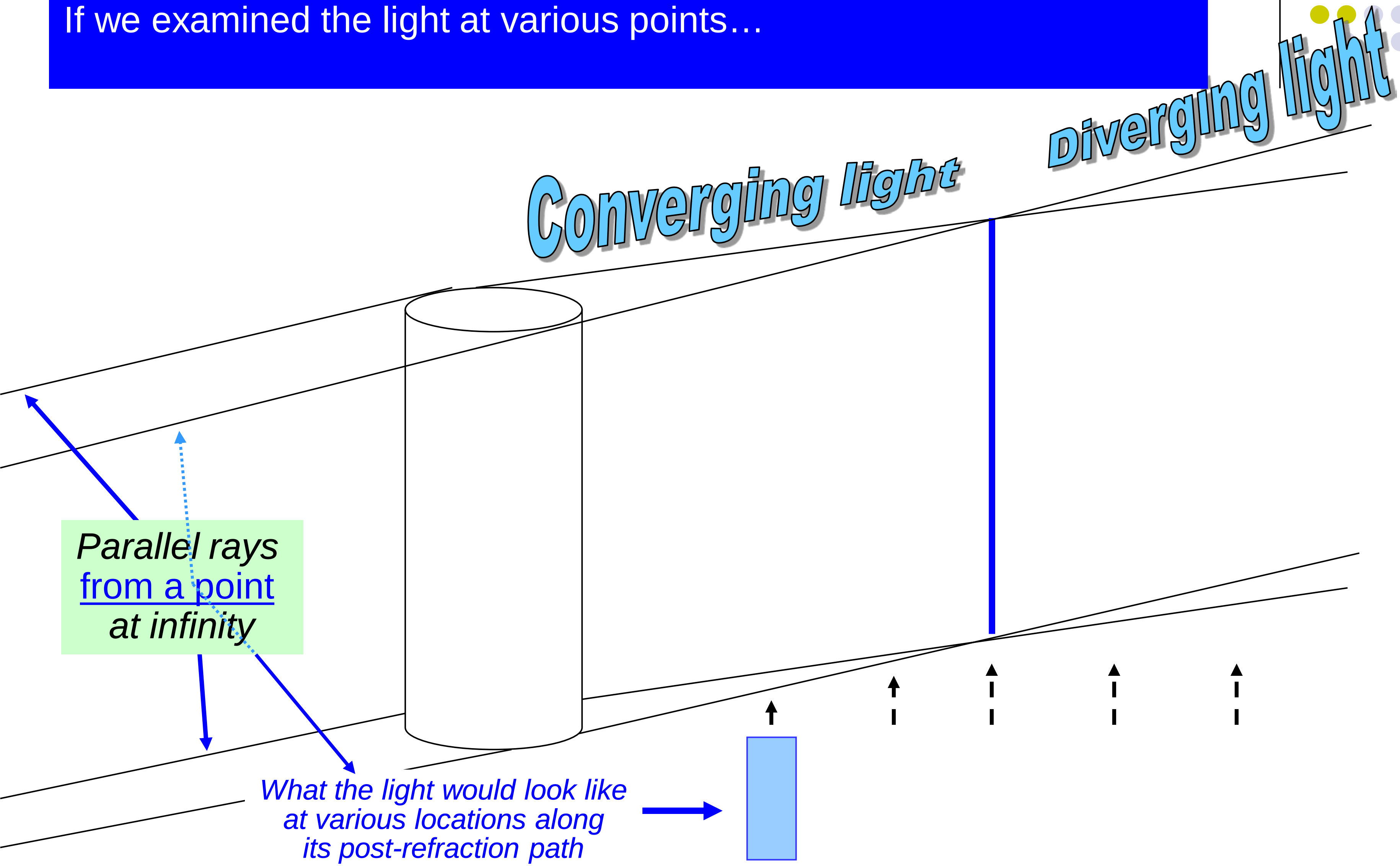

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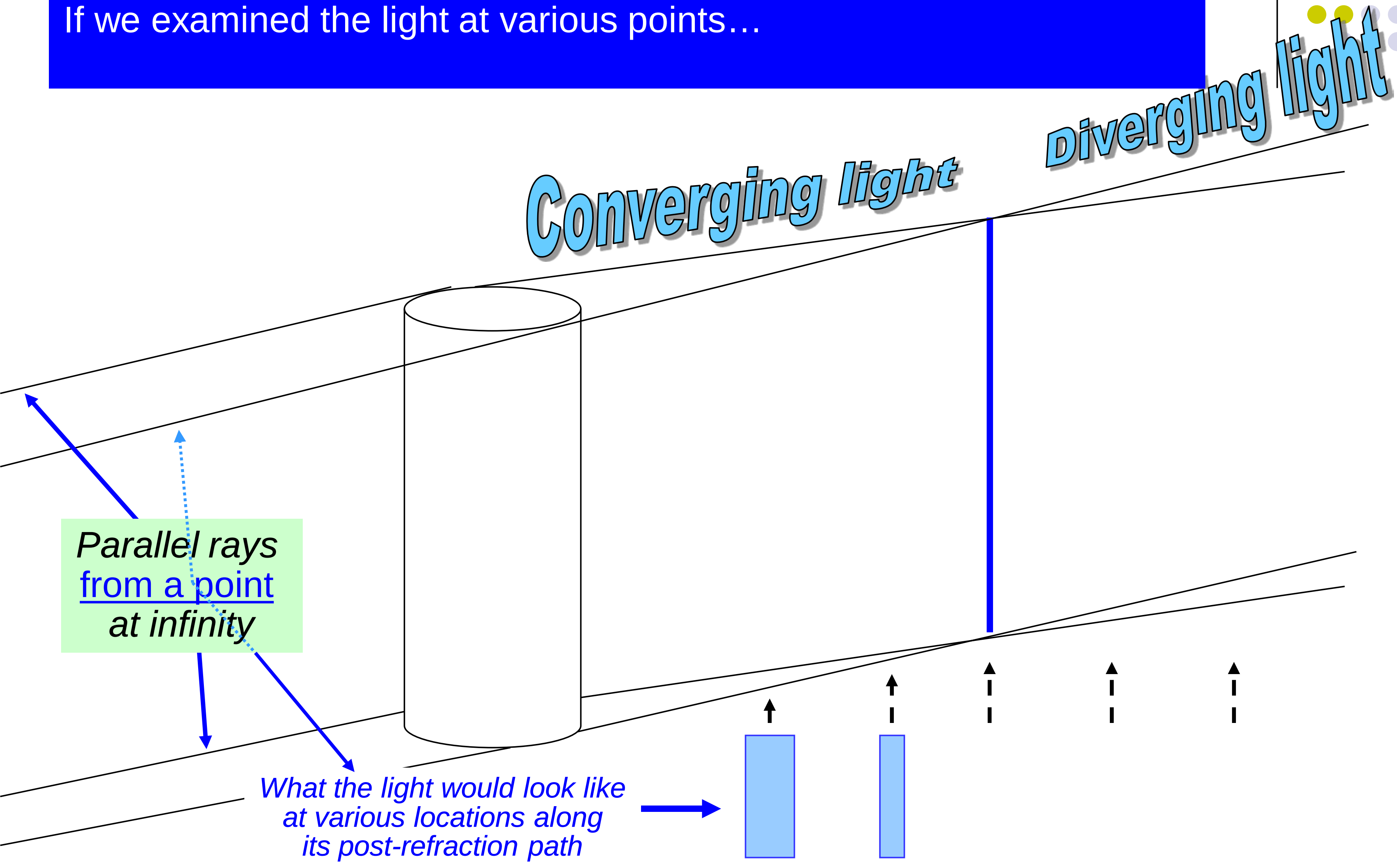

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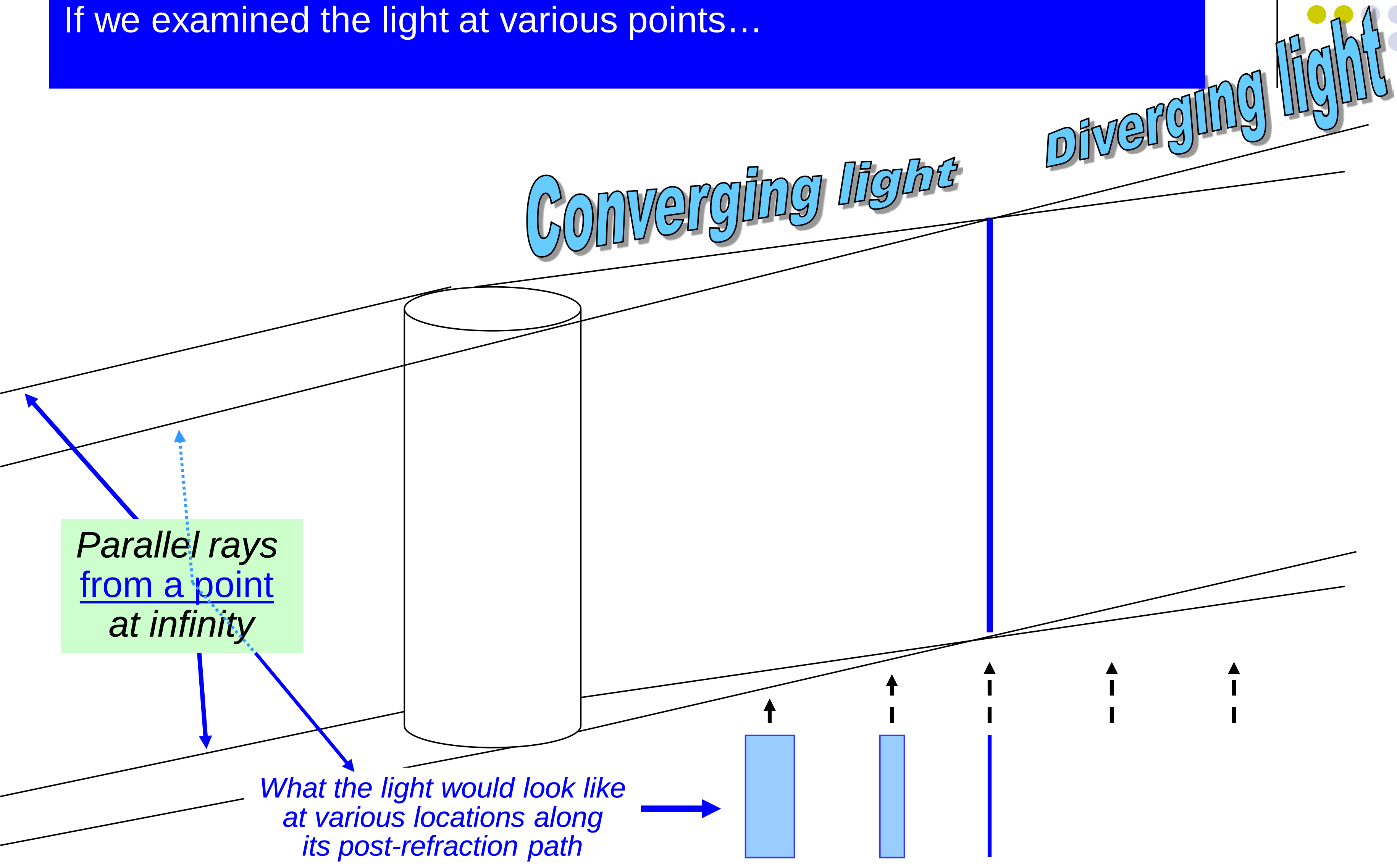

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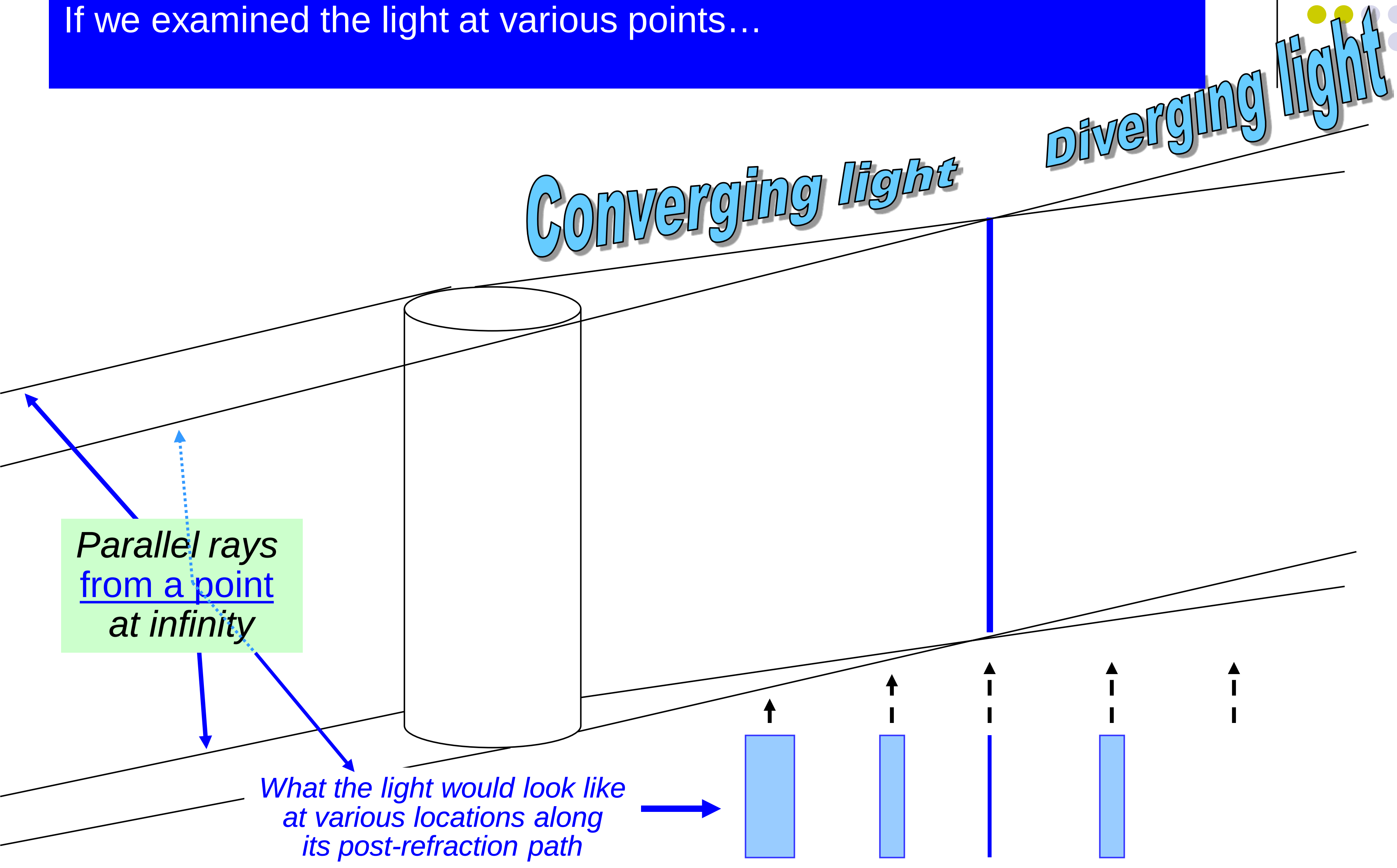
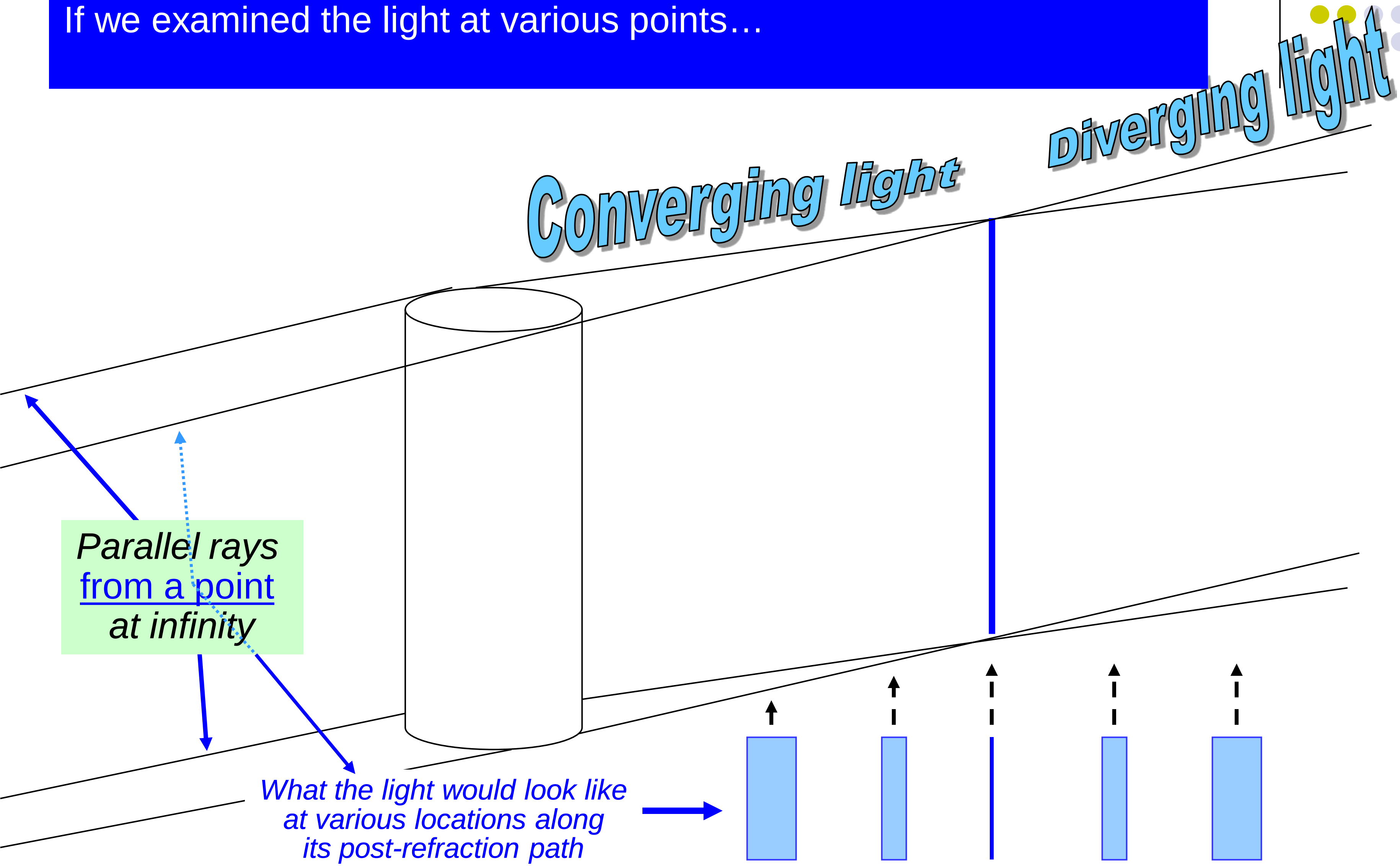


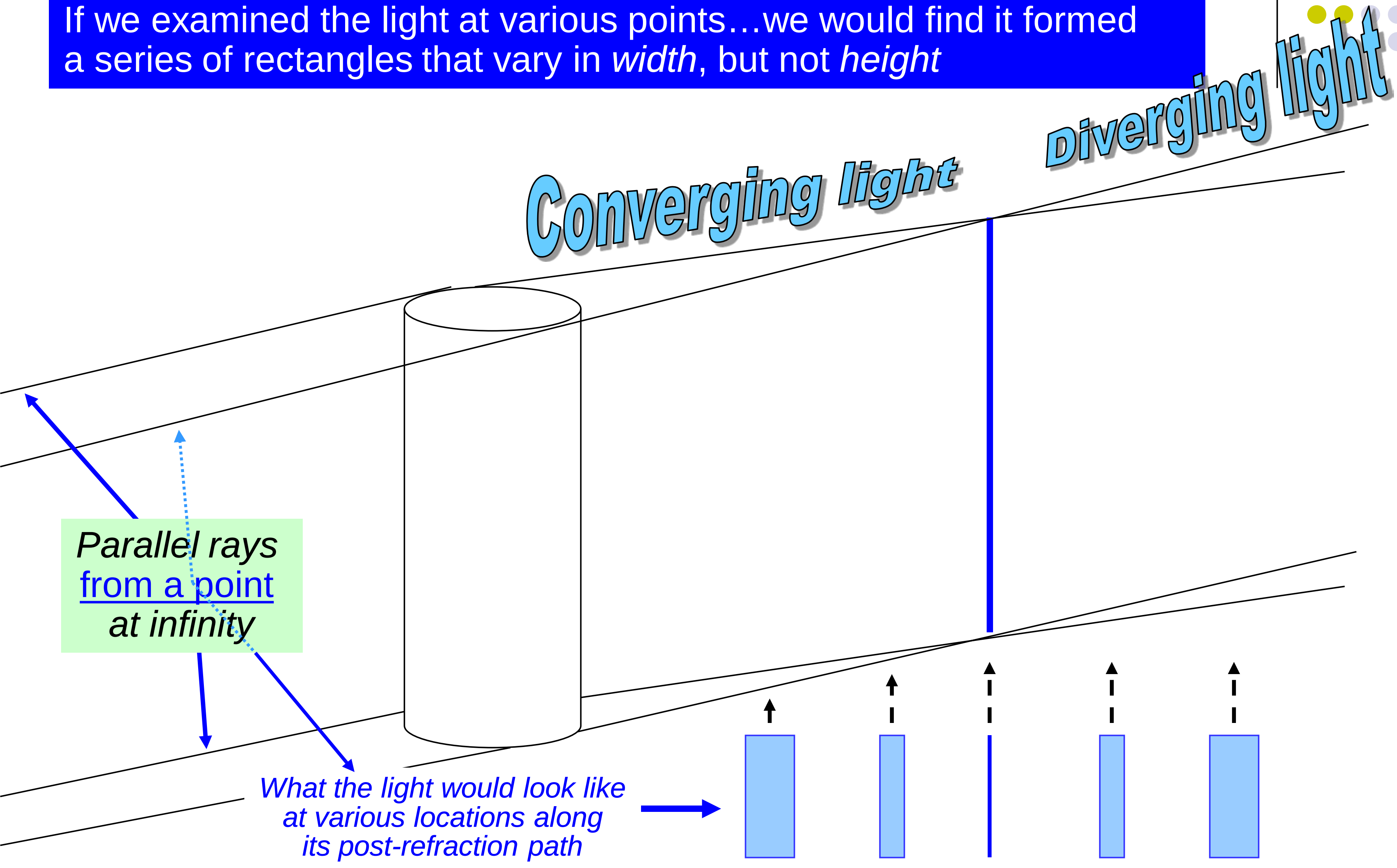
Spherocylindrical Lenses

If we examined the light at various points…

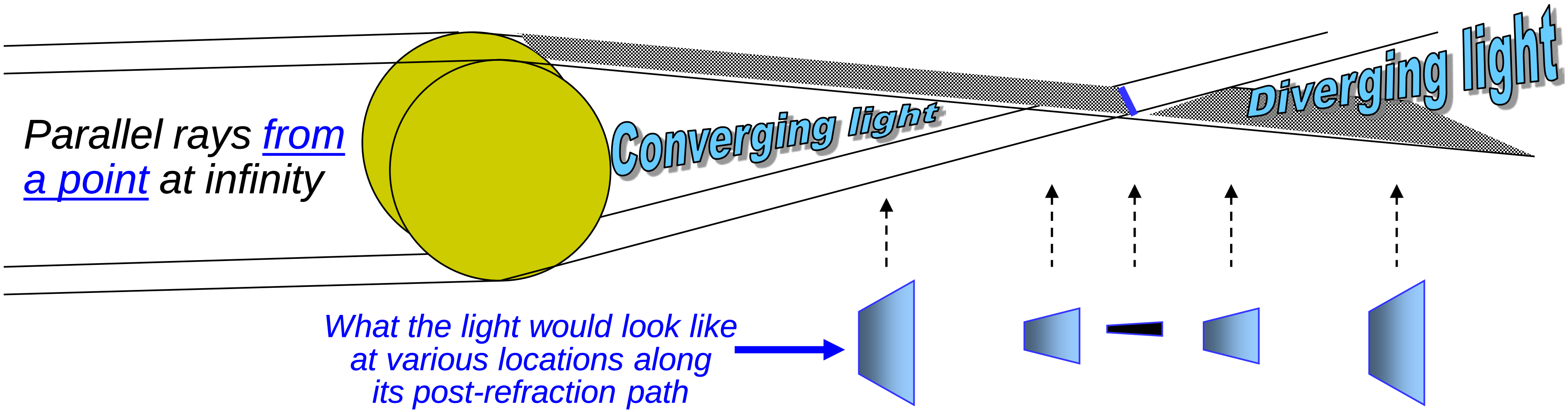


Spherocylindrical Lenses

If we examined the light at various points…we would find it formed a series of rectangles that vary in *width*, but not *height*

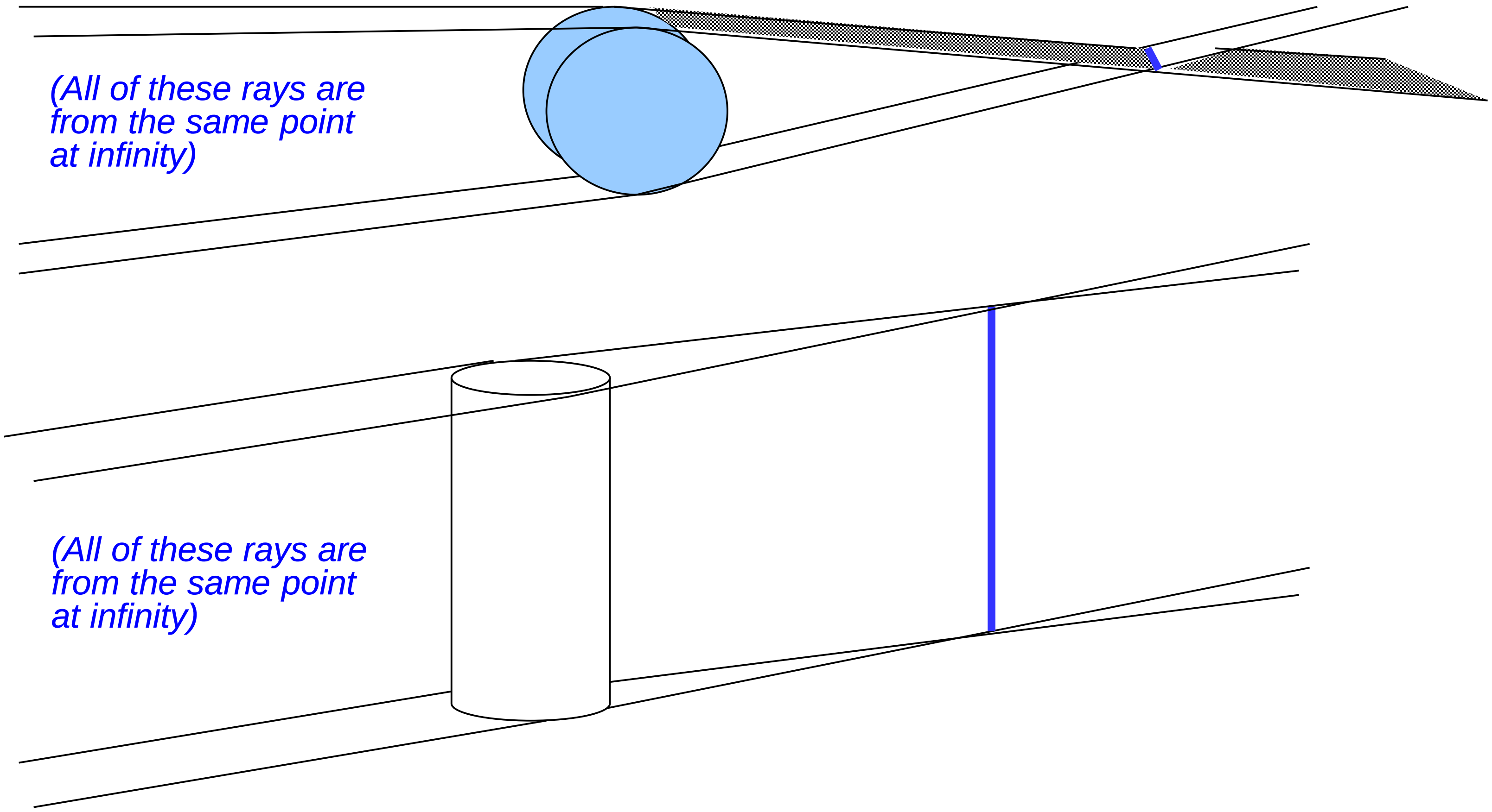


Spherocylindrical Lenses



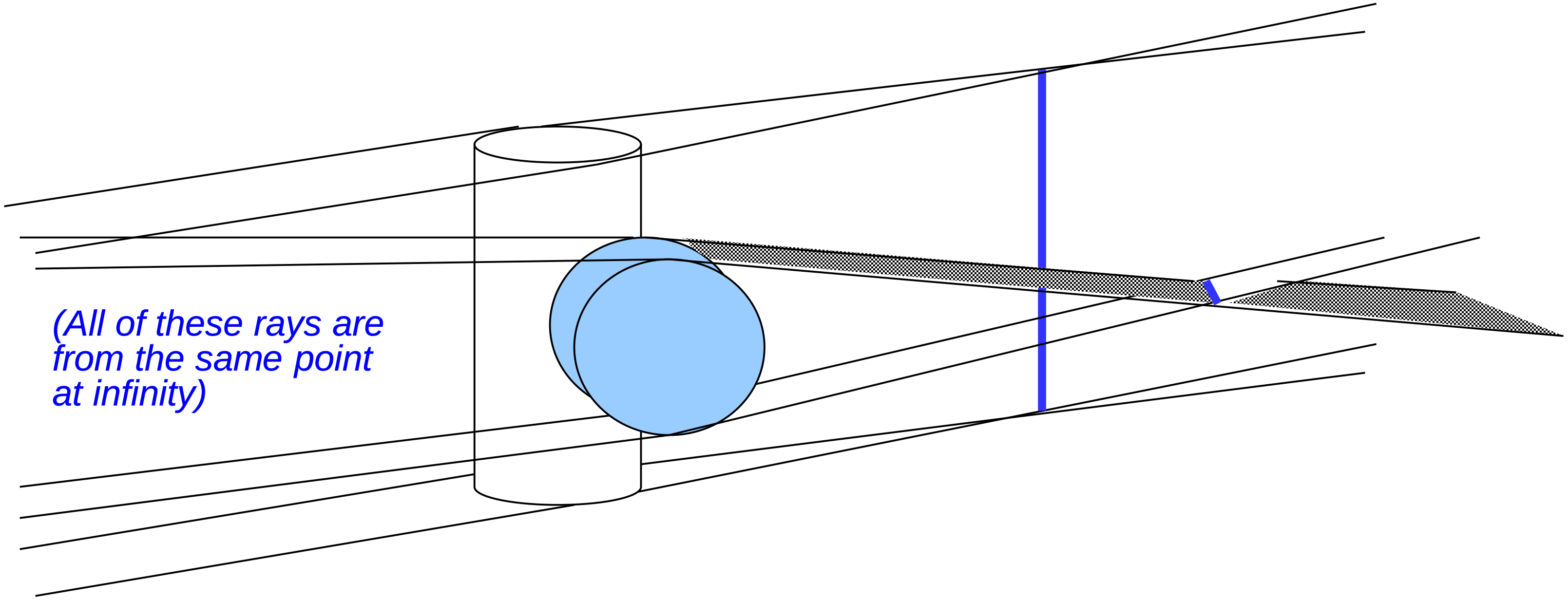
With *this* cylinder orientation, the light forms a series of rectangles that vary in *height*, but not *width*

Spherocylindrical Lenses



So, if a spherocylindrical lens is composed of two cylindrical lenses of different dioptric powers oriented 90º apart…

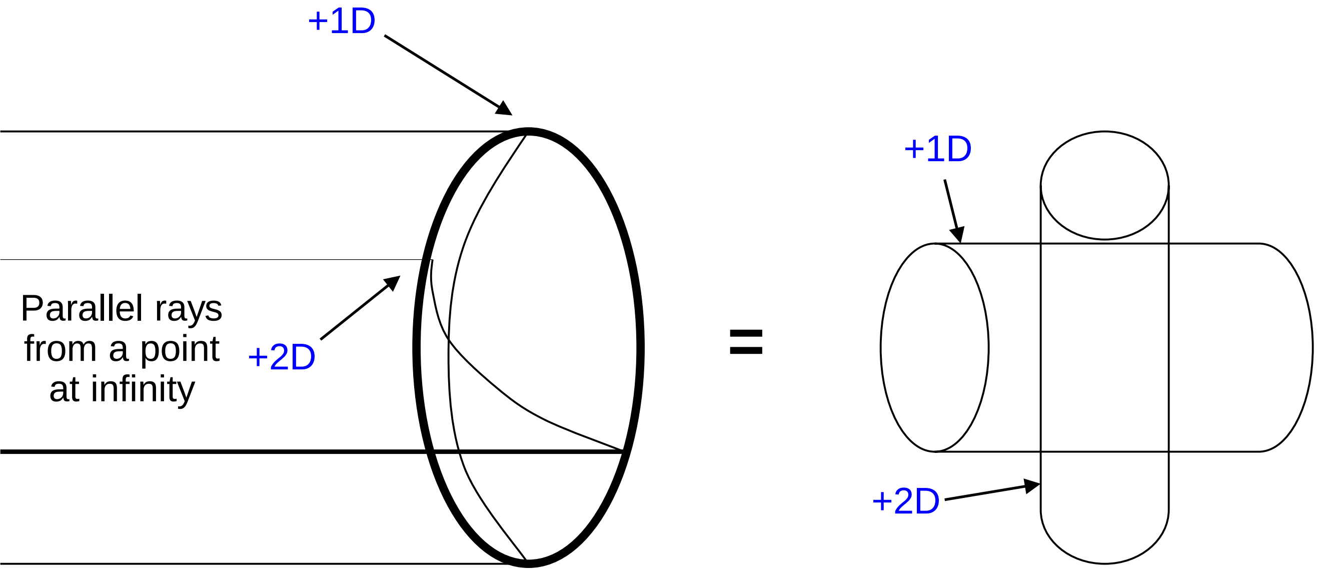
Spherocylindrical Lenses



So, if a spherocylindrical lens is composed of two cylindrical lenses of different dioptric powers oriented 90º apart…a spherocylindrical lens must do something like this. Let’s examine it in more detail.

Spherocylindrical Lenses

Consider a spherocylindrical lens that is the dioptric equivalent of +1D and +2D cylinders oriented thusly:



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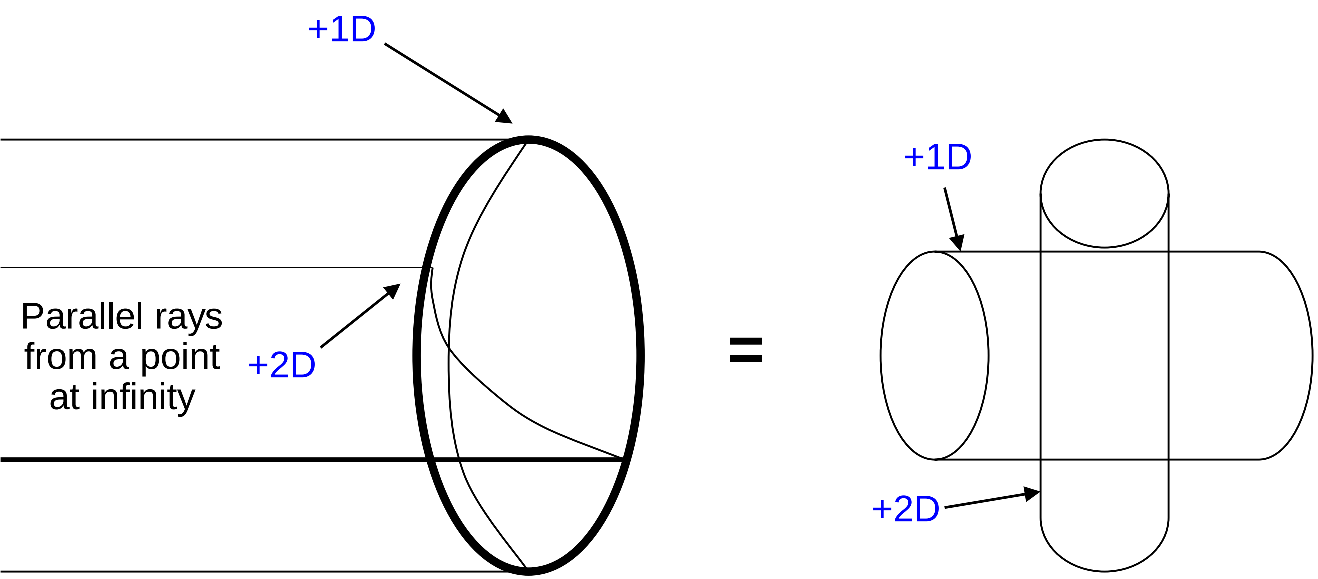
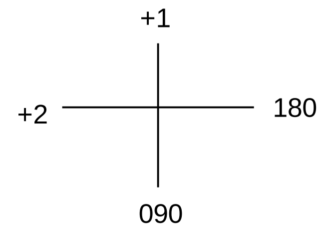


Note: *The +1D and +2D labels are pointing to the* **meridia** *of power (090 and 180, respectively). The* ***axis*** *of +1D power is at 180; of +2D, 090.*

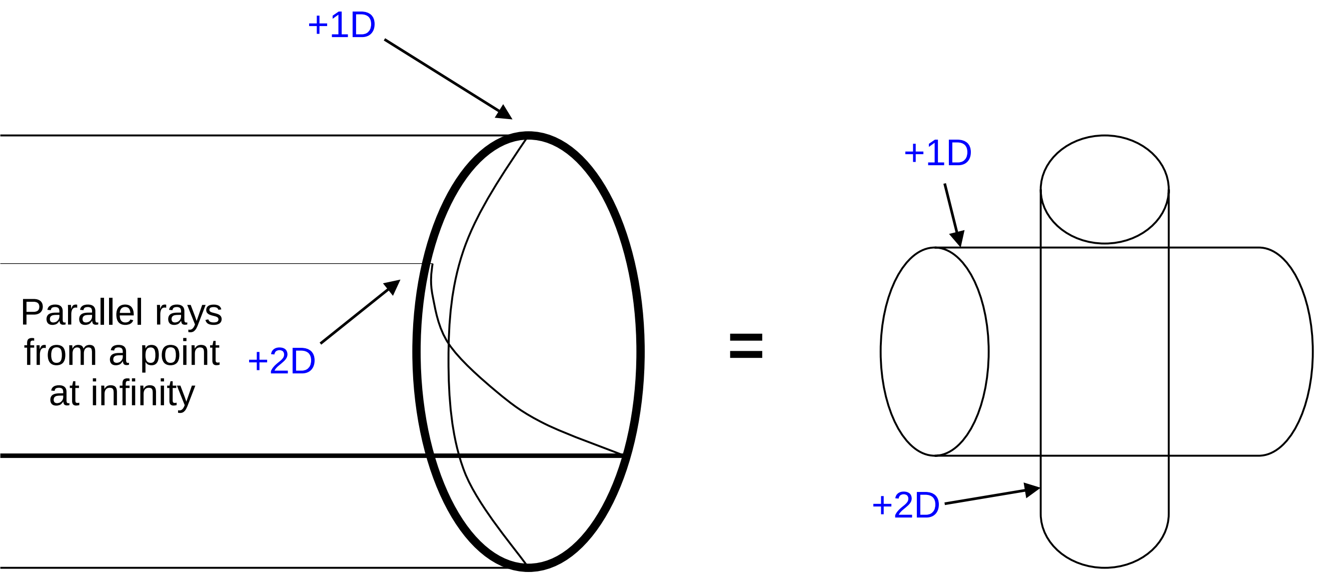
In power-cross format, it would be written:



(By the way, I know power crosses are confusing and intimidating. We'll defang them in a future chapter.)

Spherocylindrical Lenses

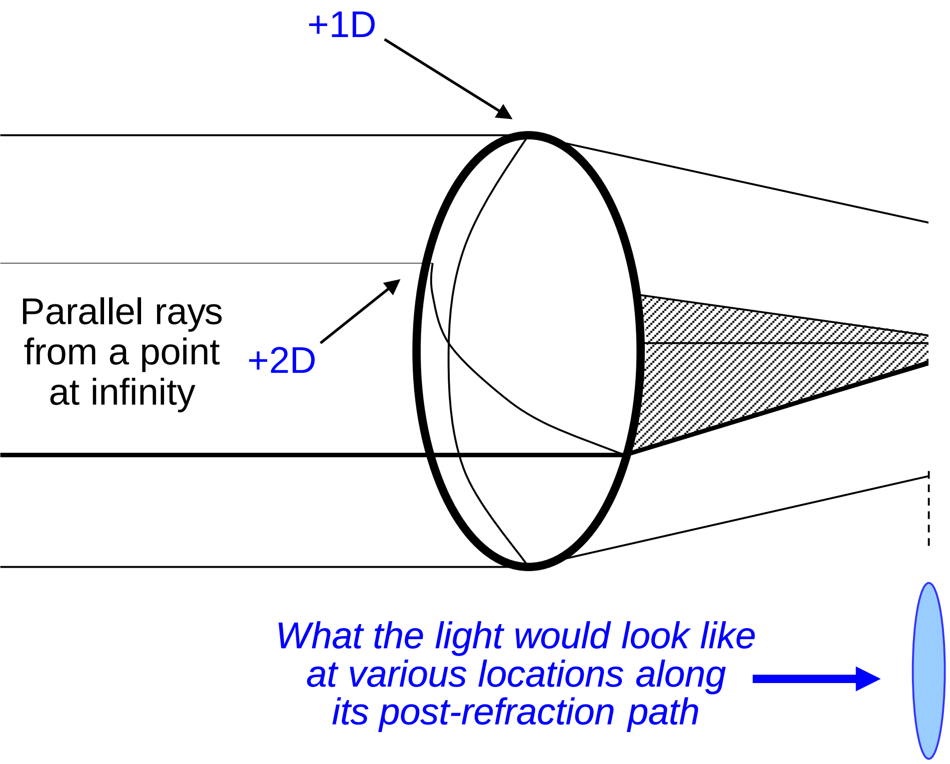
Consider a spherocylindrical lens that is the dioptric equivalent of +1D and +2D cylinders oriented thusly:



Note: *The +1D and +2D labels are pointing to the* **meridia** *of power (090 and 180, respectively). The* ***axis*** *of +1D power is at 180; of +2D, 090.*

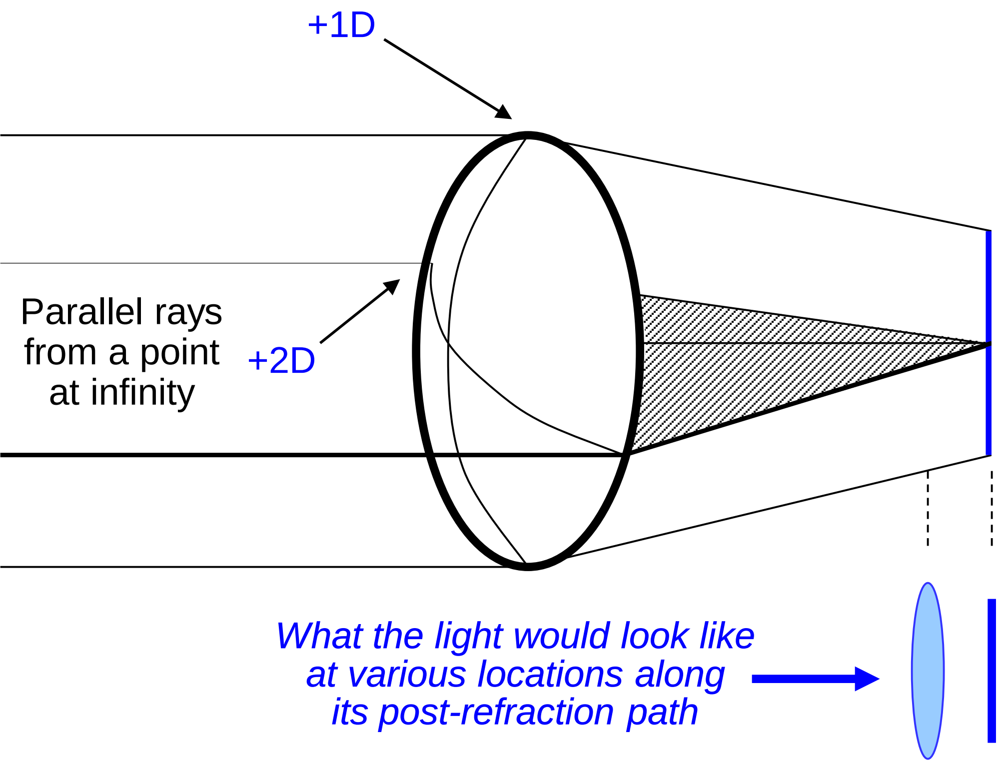
Let's examine the light as it moves along its post-refraction path

Spherocylindrical Lenses



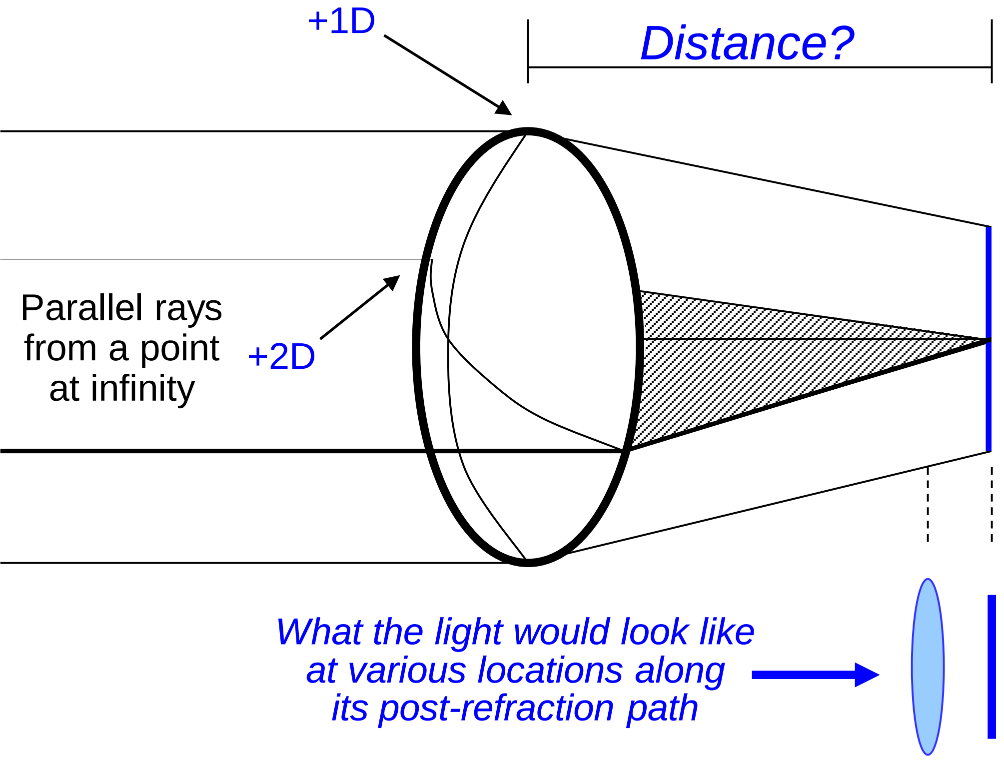
The rays are converging in both vertical and horizontal aspects. The horizontal is converging faster because there is more power in that meridian.

Spherocylindrical Lenses



The rays have converged further to form a *vertical focal line*. Note that the rays are continuing to converge vertically as well (i.e., the line is shorter than the previous oval).

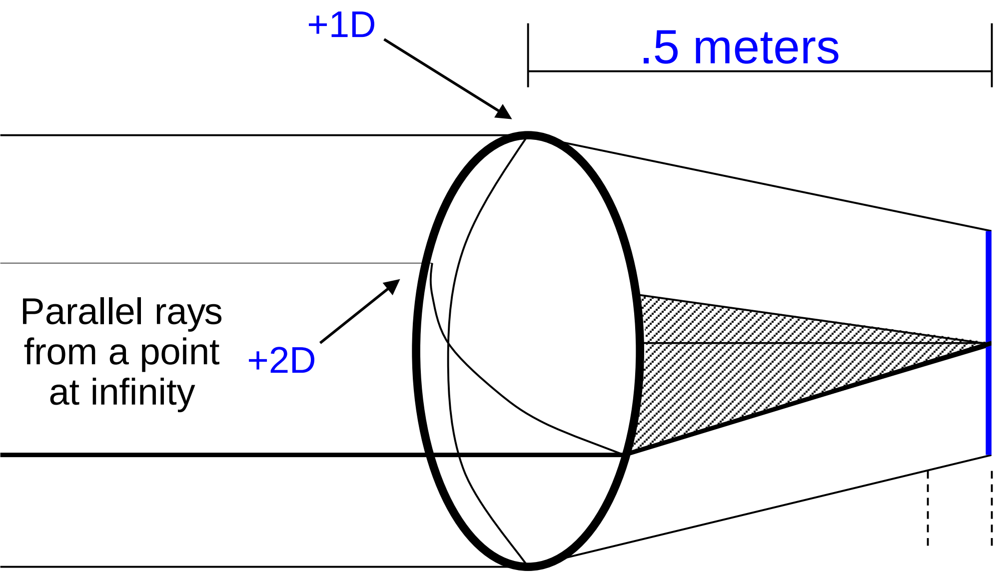
Spherocylindrical Lenses



What the light would look like at various locations along its post-refraction path

The rays have converged further to form a *vertical focal line*. Note that the rays are continuing to converge vertically as well (i.e., the line is shorter than the previous oval). *What is the distance from the lens to this anterior focal line?*

Spherocylindrical Lenses



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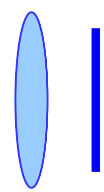
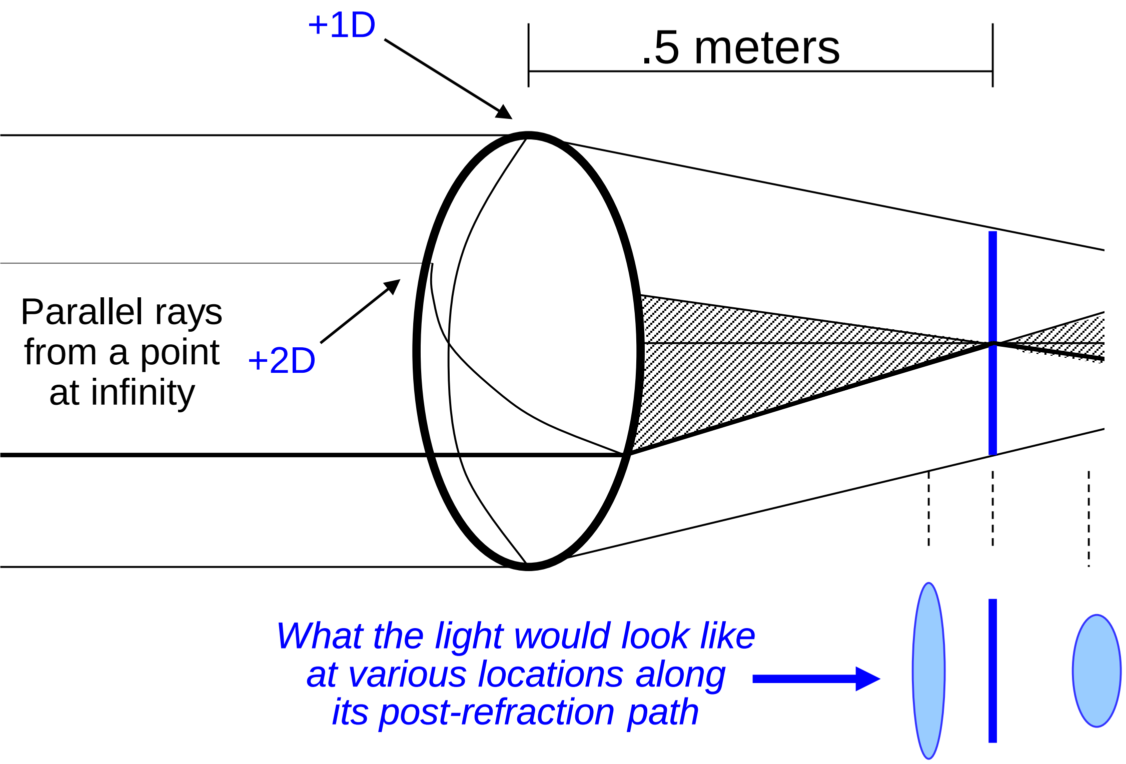


The rays have converged further to form a *vertical focal line*. Note that the rays are continuing to converge vertically as well (i.e., the line is shorter than the previous oval). ***What is the distance from the lens to this anterior focal line?***

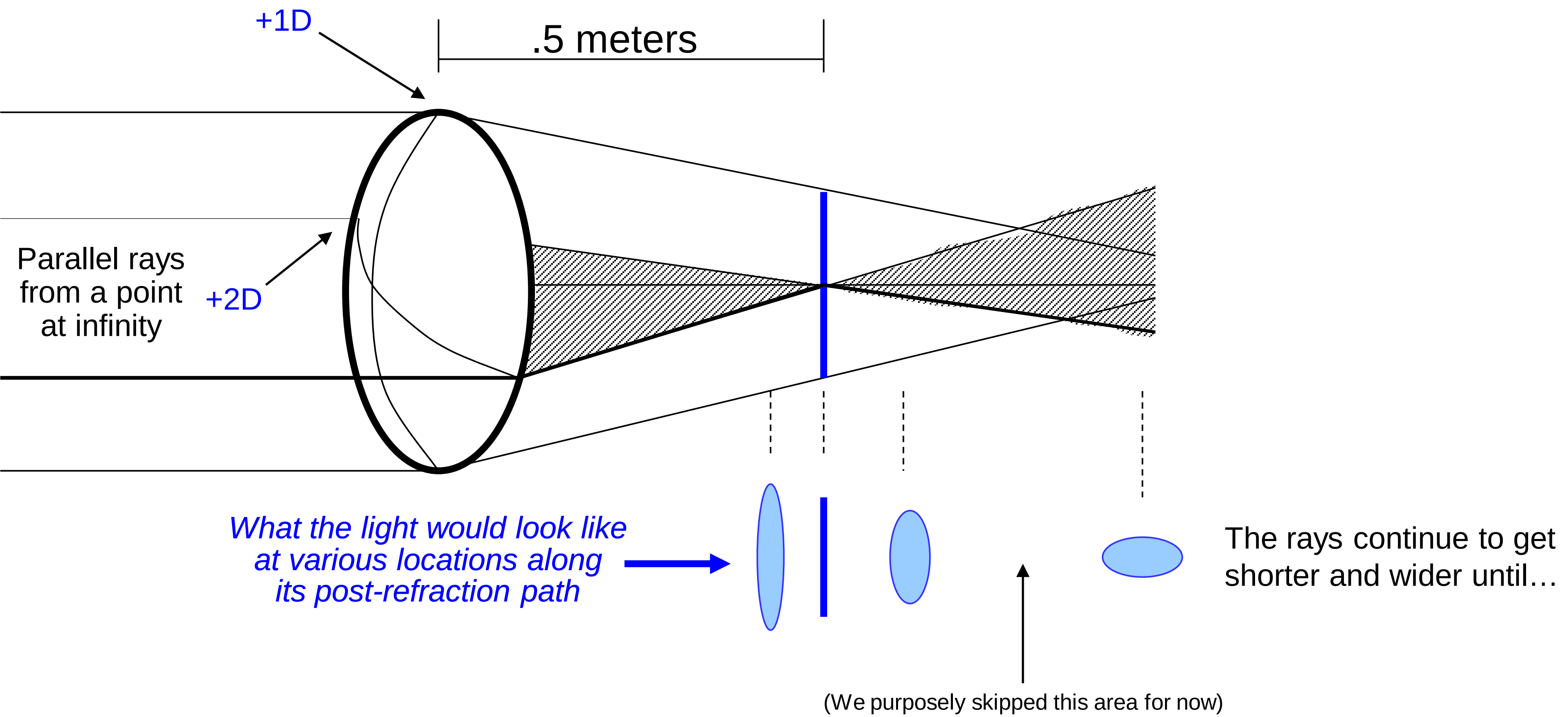
A +2D cylinder will form a focal **line** at a distance of 1/2 = .5 meters.

Spherocylindrical Lenses

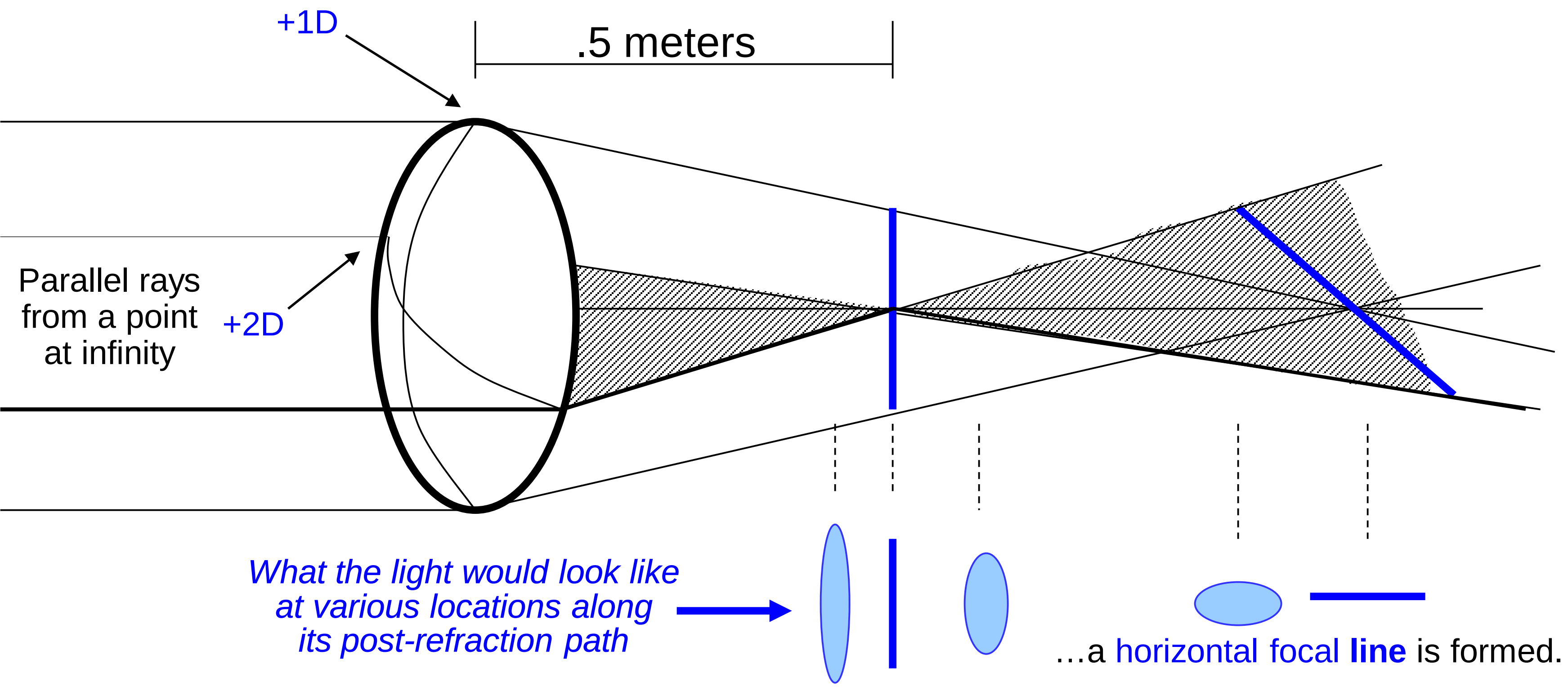


The rays are continuing to converge vertically, so the height of the figure continues to shrink. However, the horizontal rays, having converged to form a focal line, are now **diverging**. Thus the width is now *increasing*.

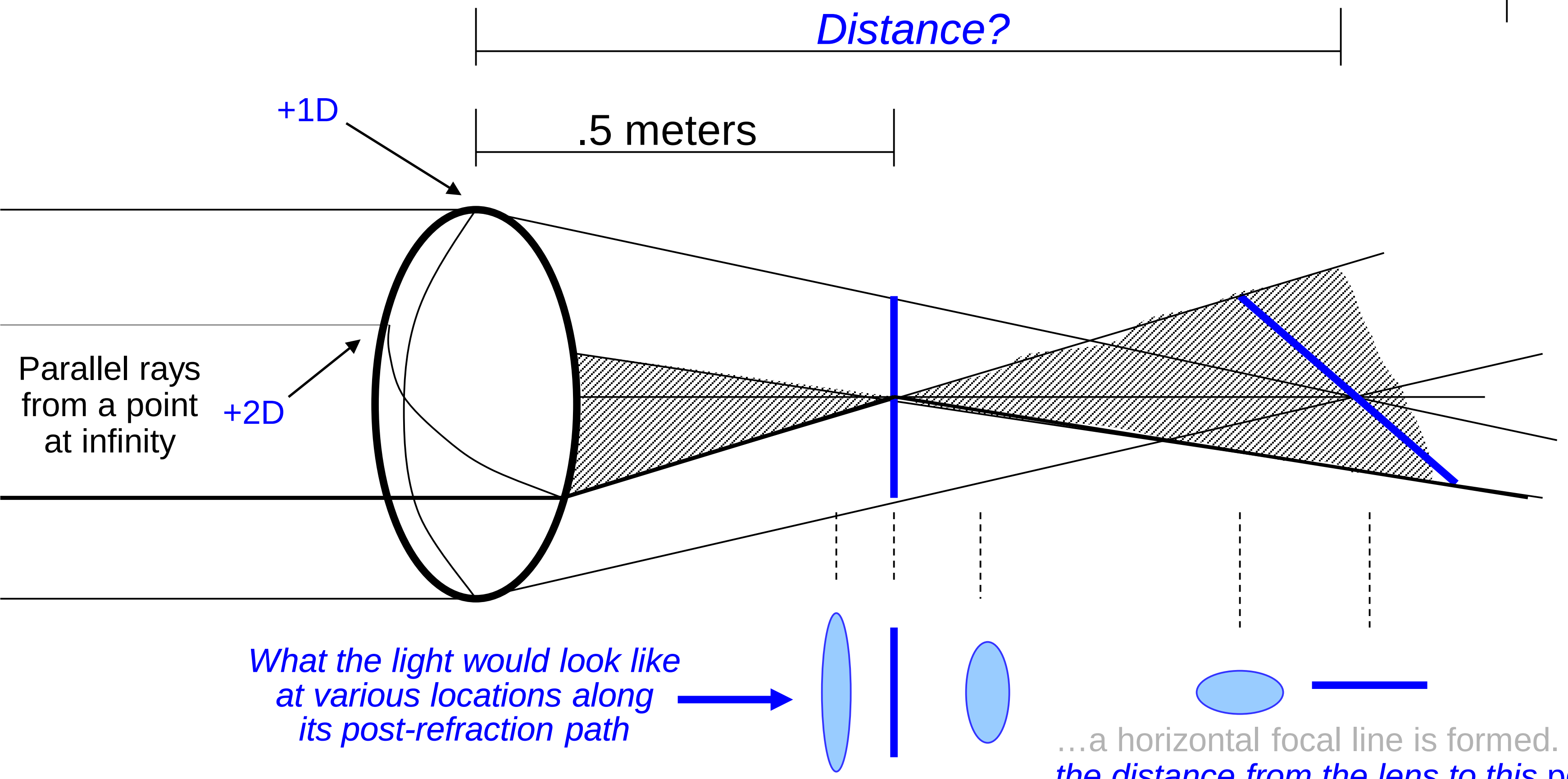
Spherocylindrical Lenses



Spherocylindrical Lenses

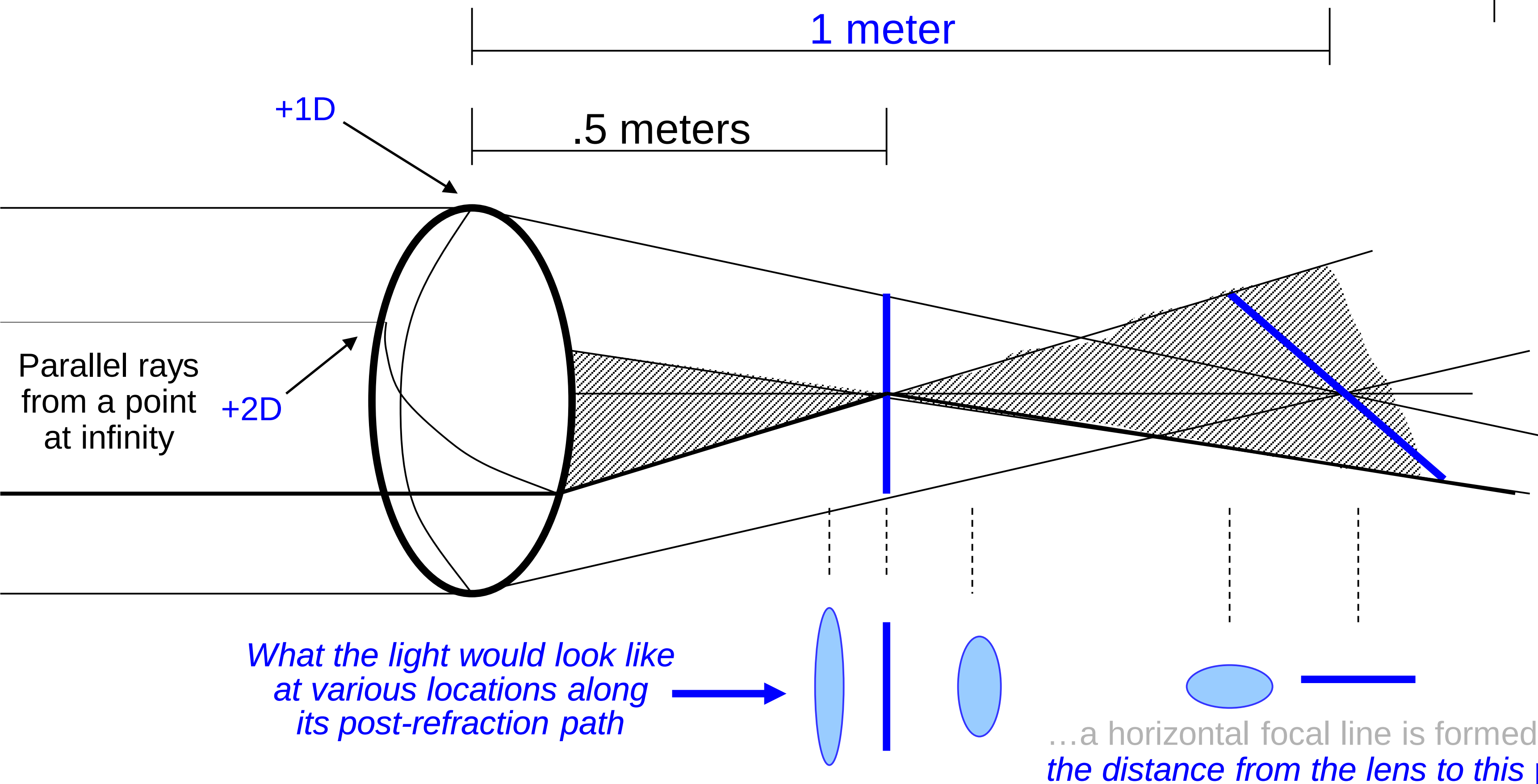


Spherocylindrical Lenses



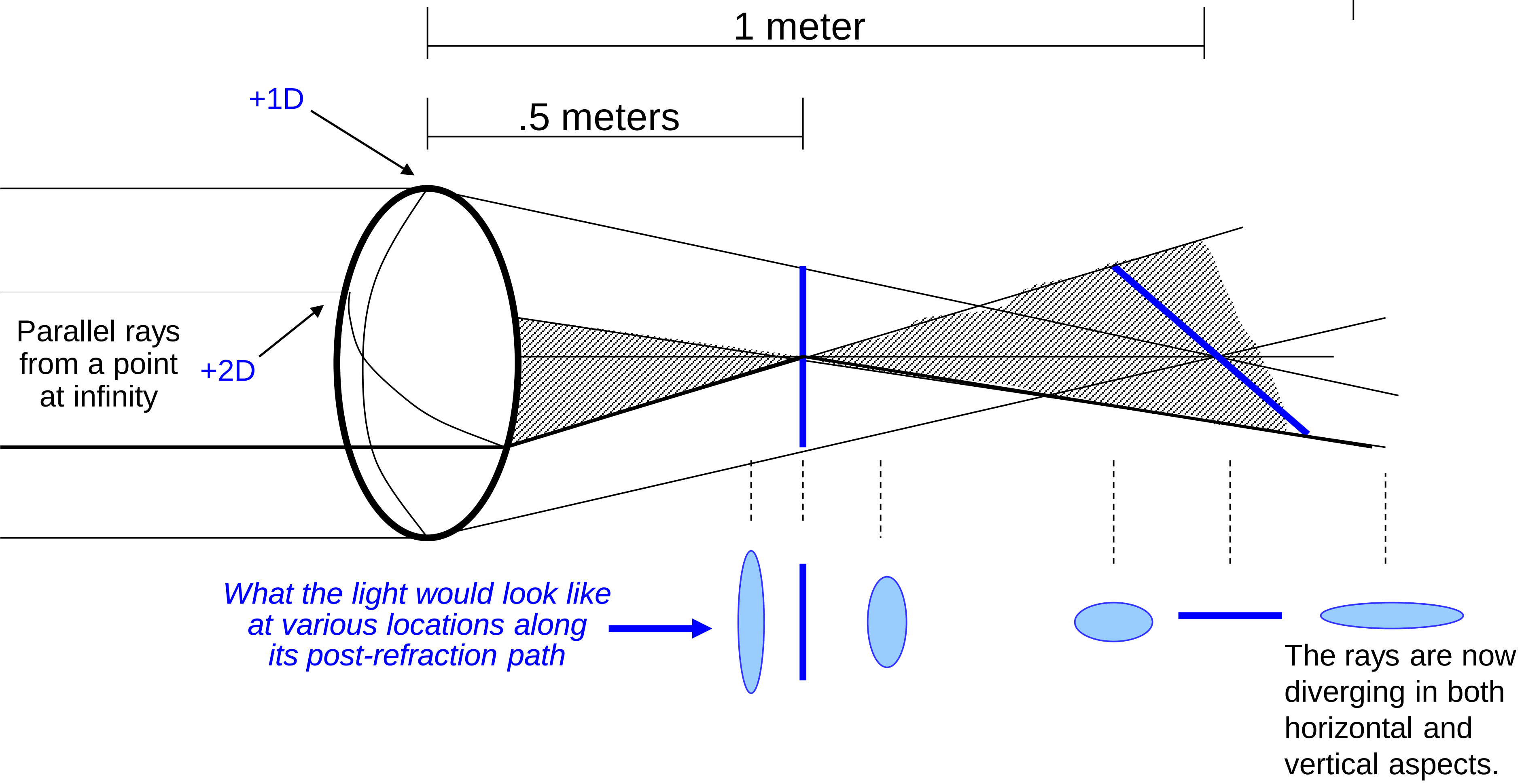
…a horizontal focal line is formed. *What is the distance from the lens to this* posterior *focal line?*

Spherocylindrical Lenses

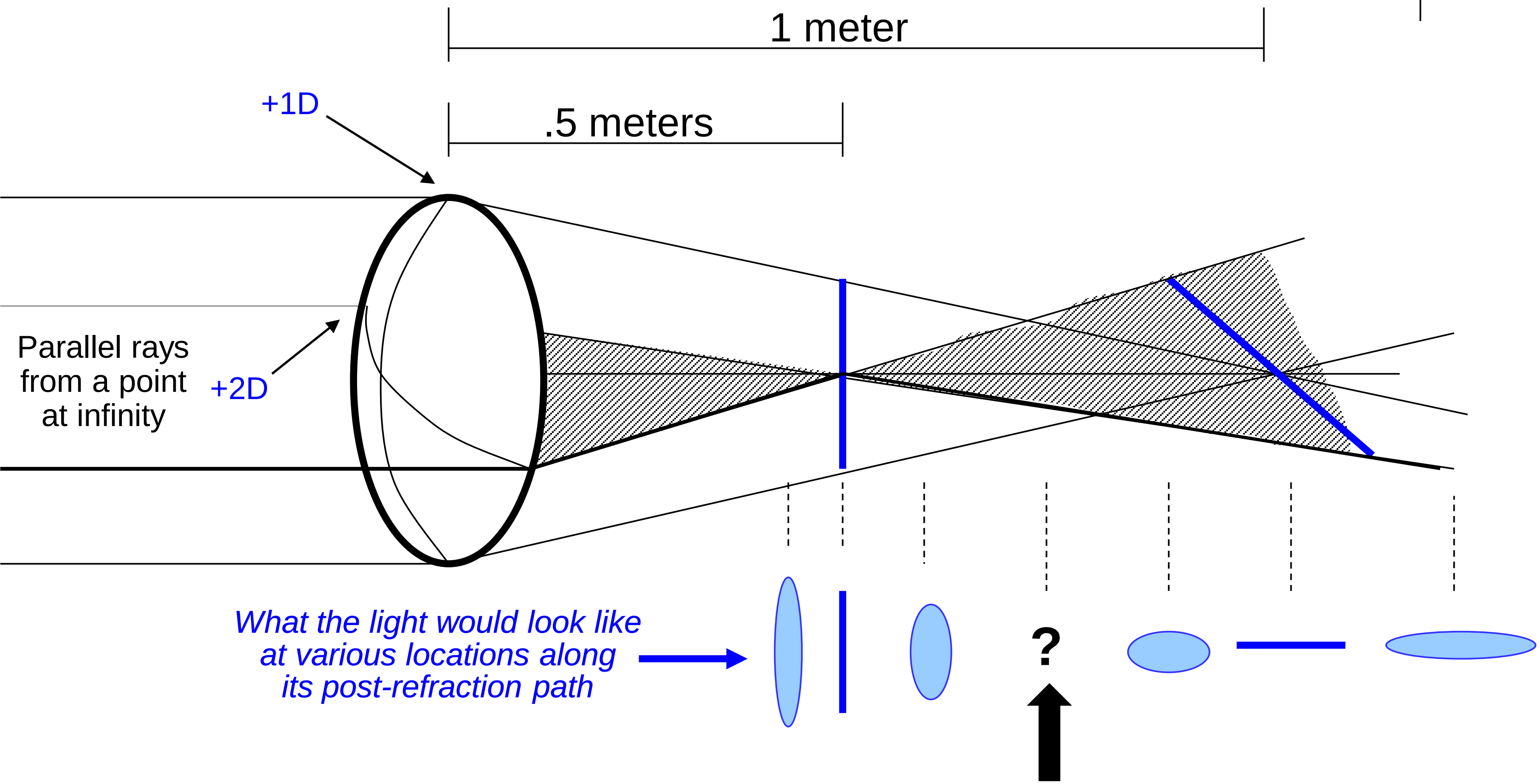


…a horizontal focal line is formed. *What is the distance from the lens to this* posterior *focal line?*
A +1D cylinder will form a focal line at a distance of 1/1 = 1 meter.

Spherocylindrical Lenses



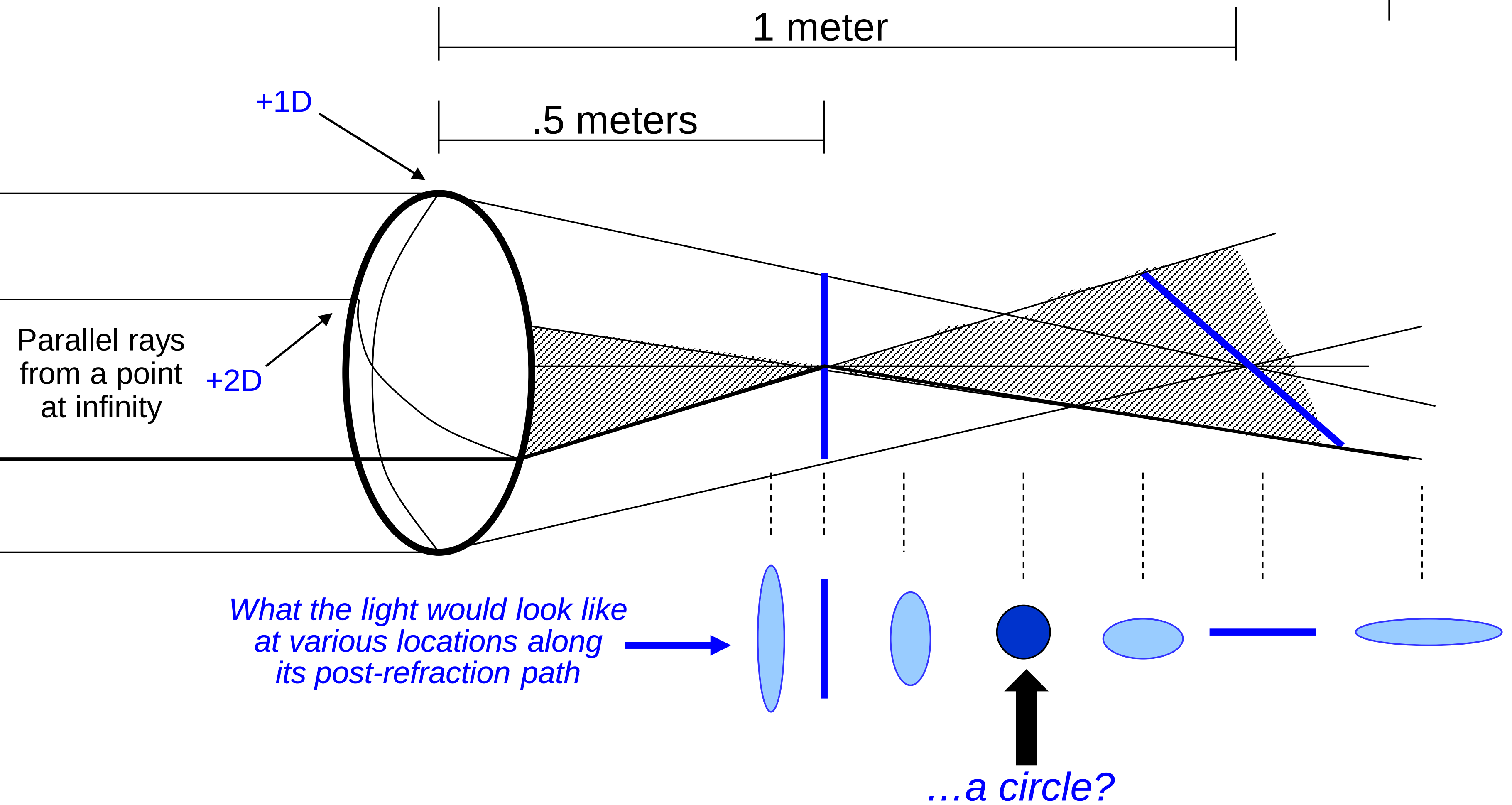
Spherocylindrical Lenses



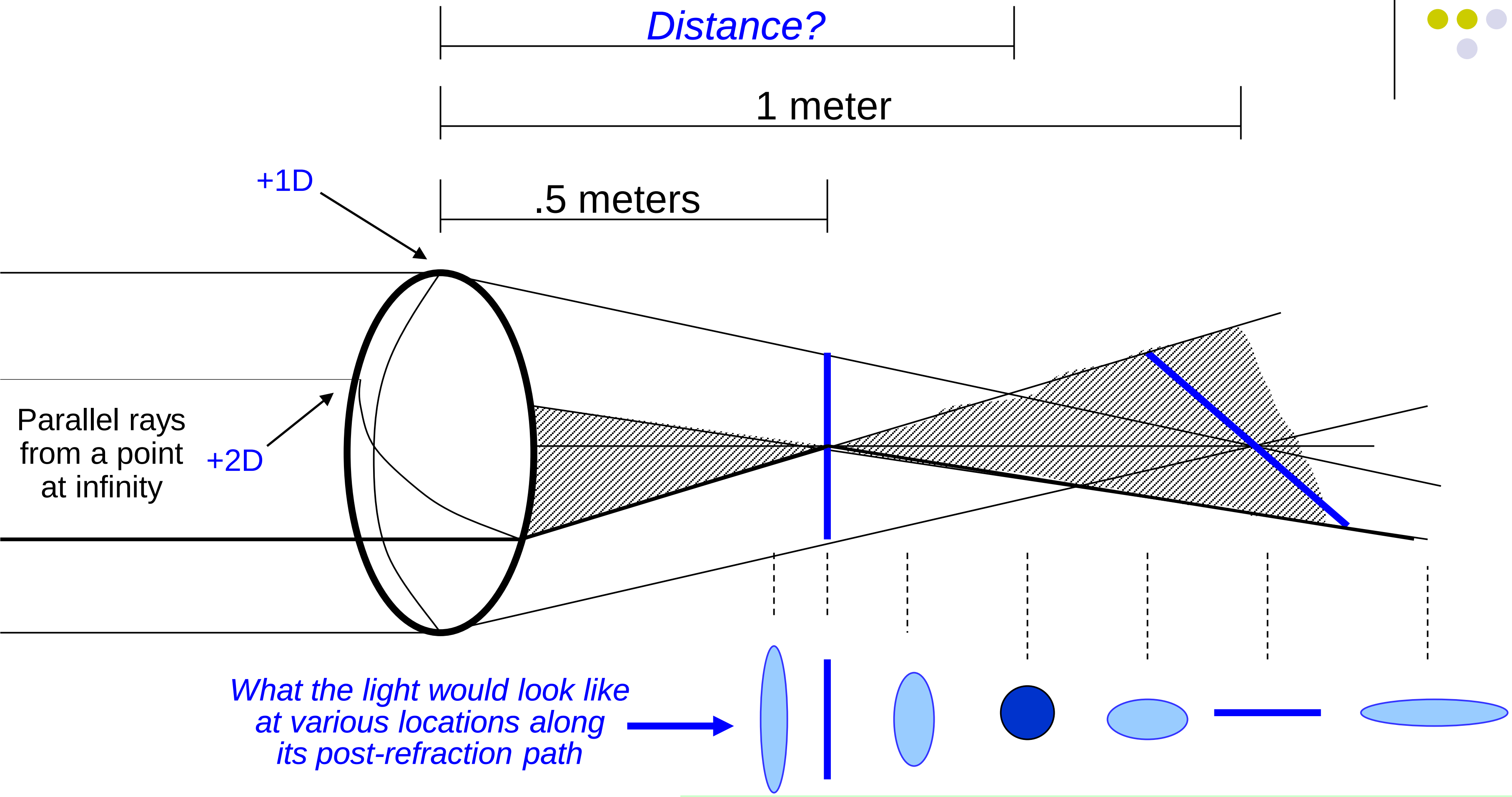
What the light would look like at various locations along its post-refraction path

Let's get back to the area we skipped. As it passes through this location, the pattern of light is morphing from a vertical oval to a horizontal oval. Does it make sense that, at some point in this process, the light pattern will form…

Spherocylindrical Lenses



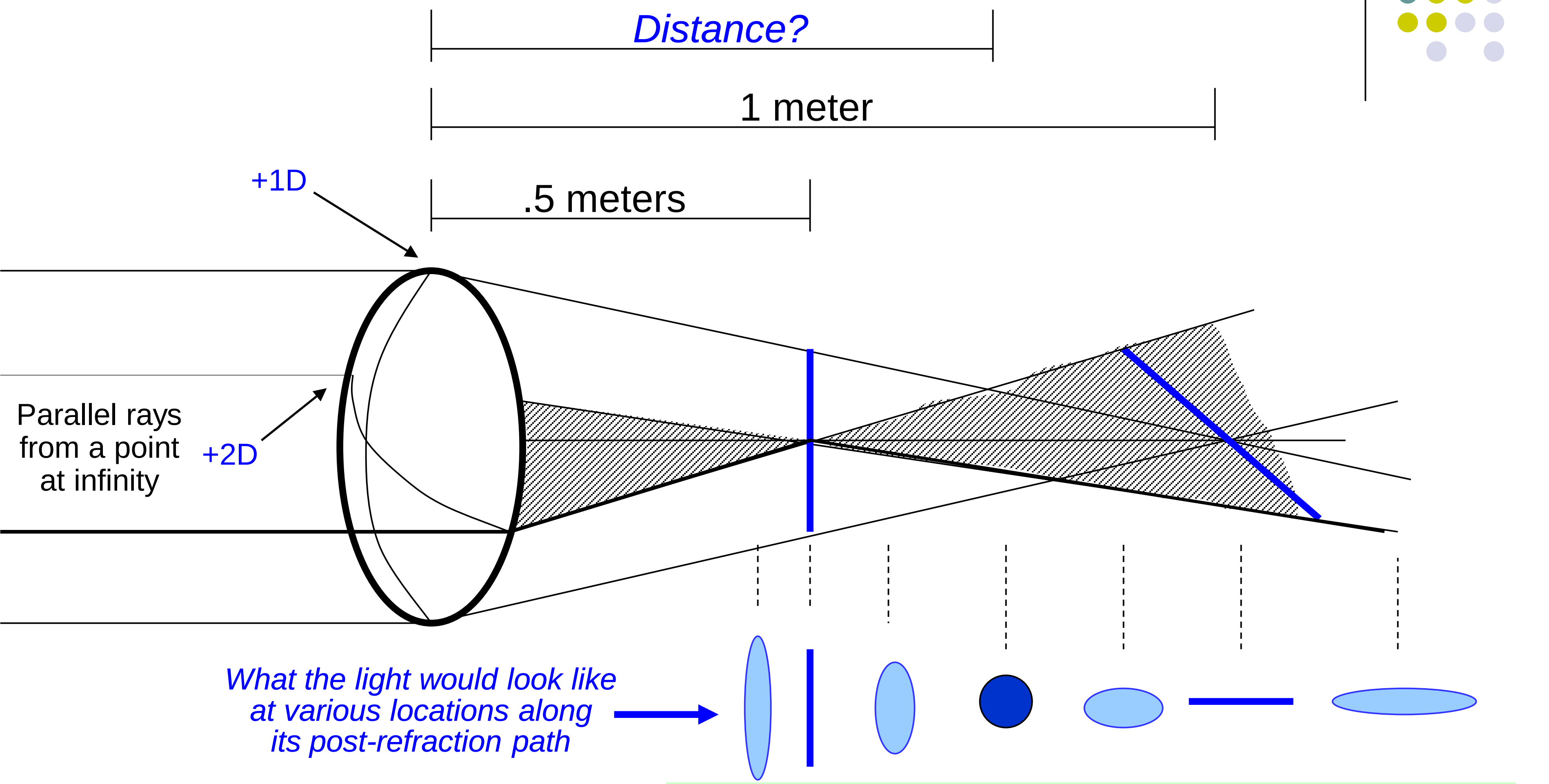
Spherocylindrical Lenses



What the light would look like at various locations along its post-refraction path

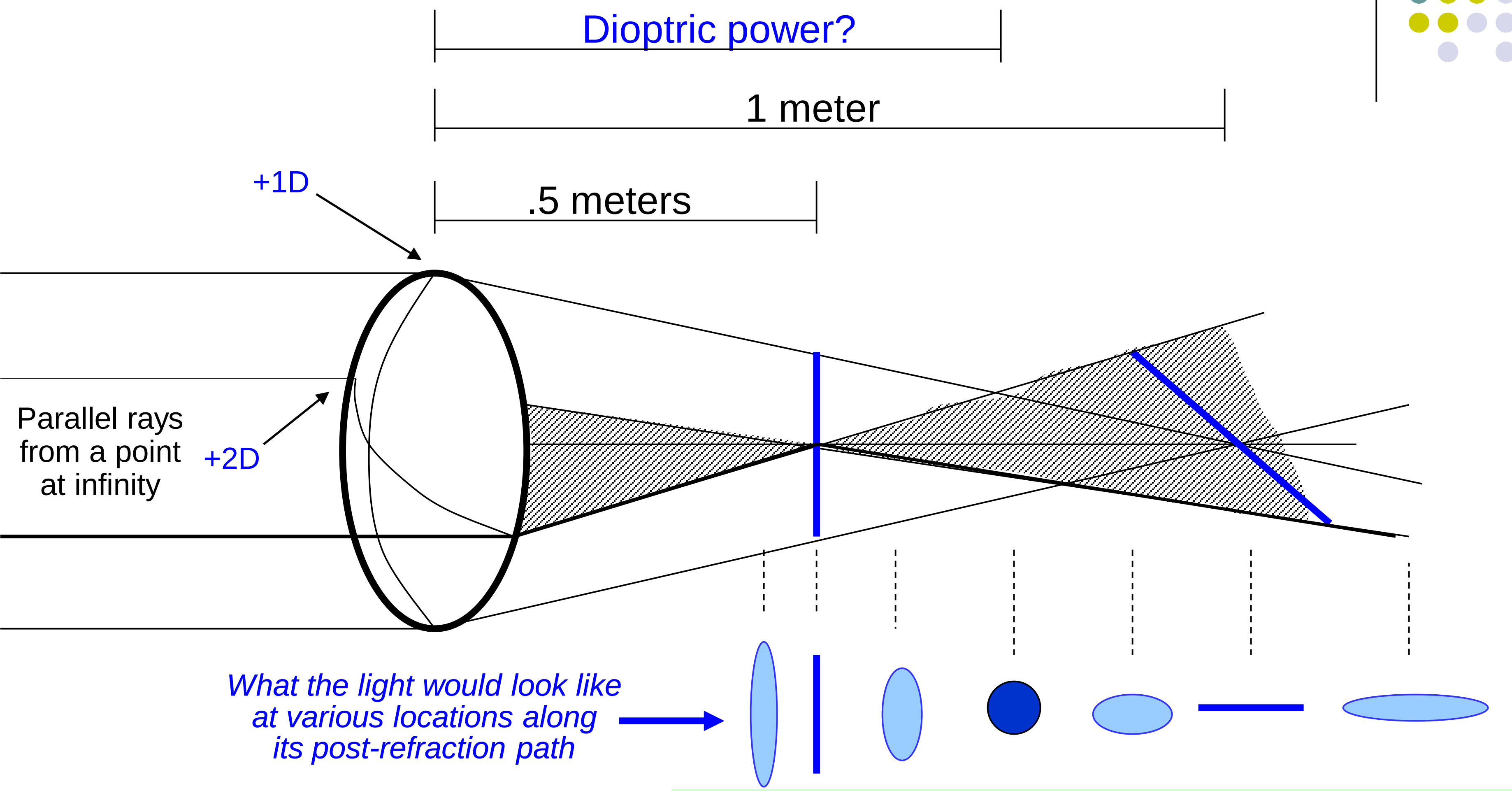
What is the distance from the lens to the circle?

Spherocylindrical Lenses



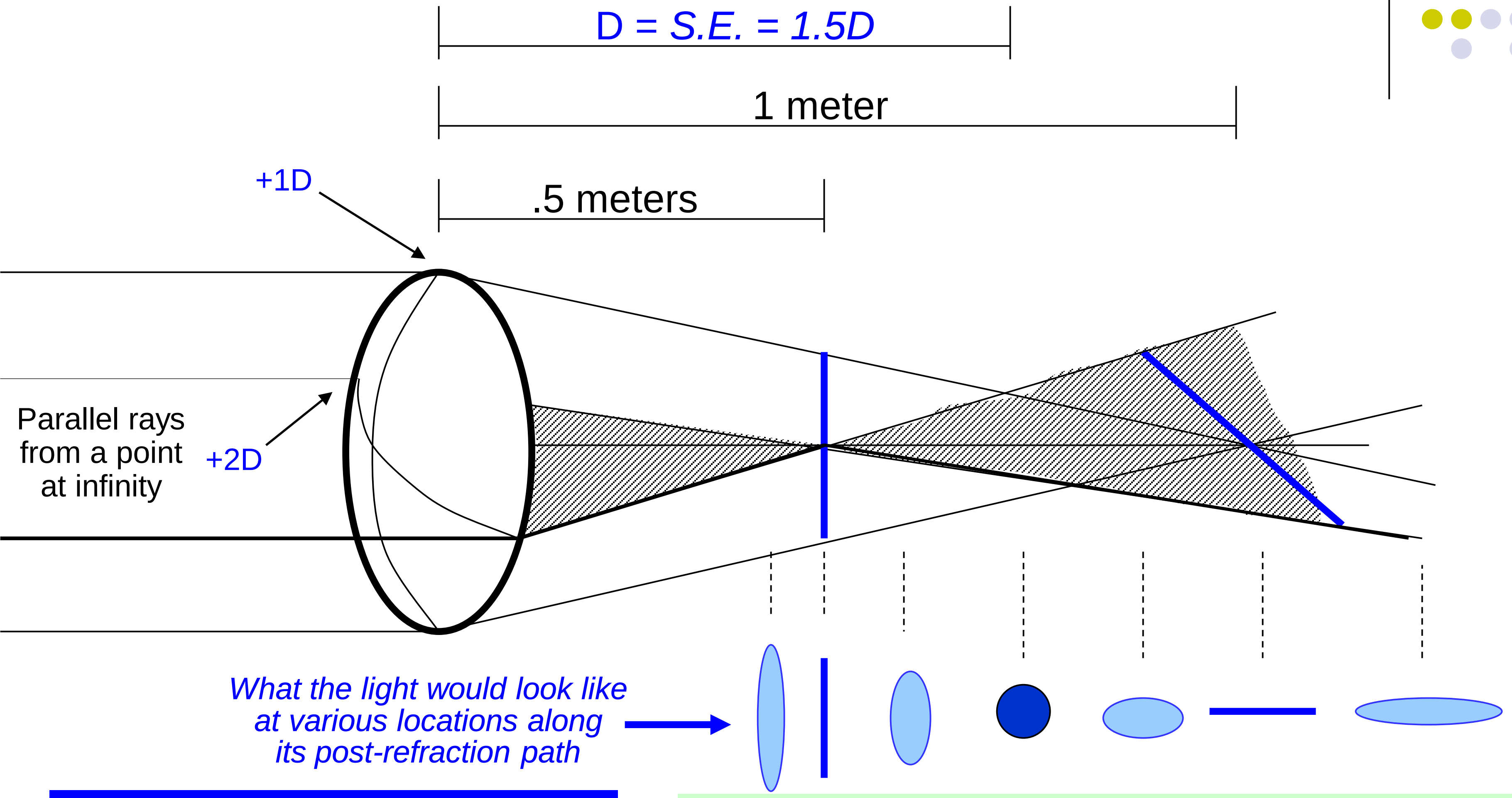
What is the distance from the lens to the circle?
To answer this we first need to determine…

Spherocylindrical Lenses



What is the distance from the lens to the circle?
To answer this we first need to determine…
What is the dioptric power associated with the circle?

Spherocylindrical Lenses

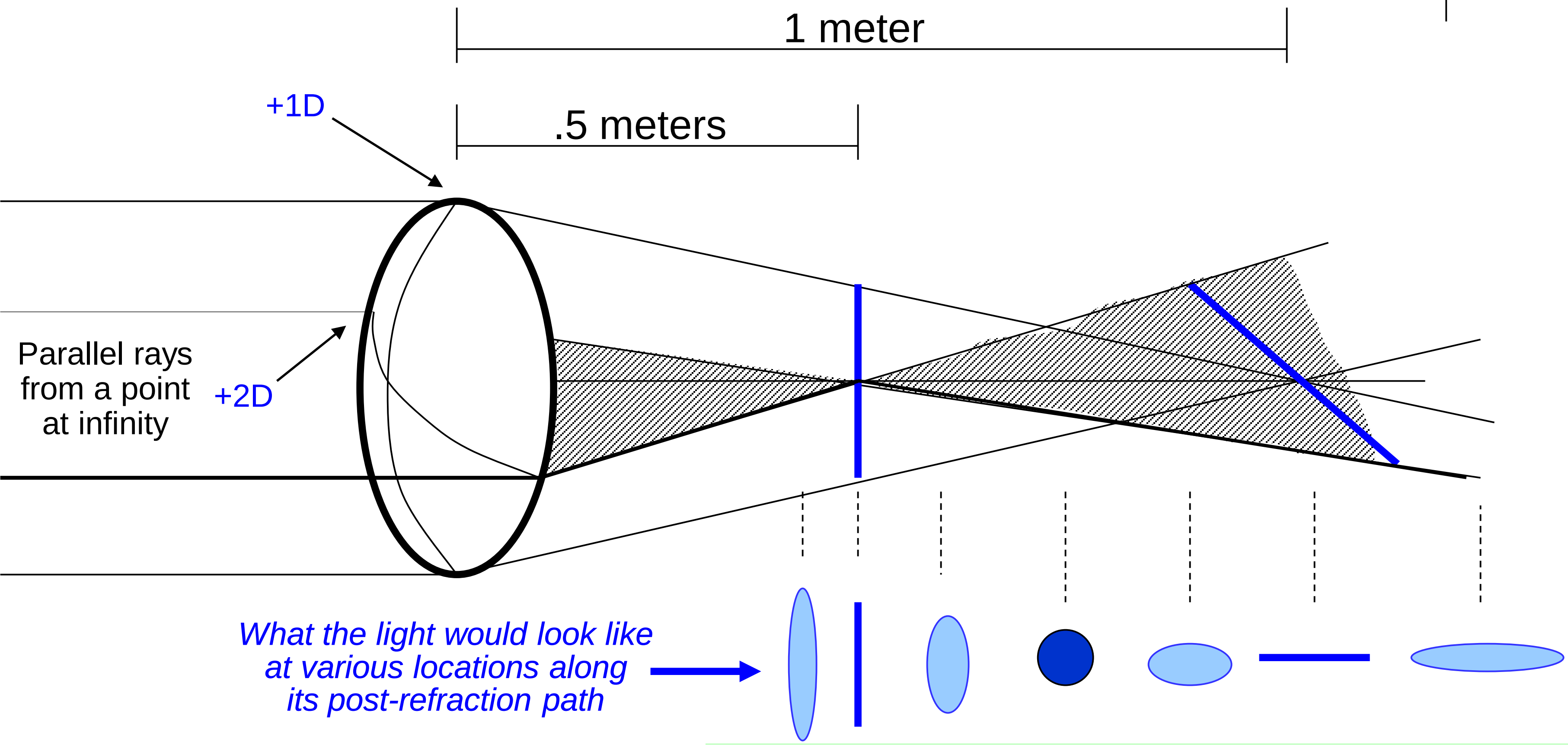


(Spherical equivalent = average power of the two cylinder lenses. In other words, a spherocylindrical lens composed of a +1D and a +2D meridian focuses light, *on average*, like a +1.50 spherical lens.)

What is the distance from the lens to the circle?
To answer this we first need to determine…
What is the dioptric power associated with the circle?
The dioptric power is the **spherical equivalent** (S.E.) of the lens--in this case, +1.50D.

Spherocylindrical Lenses

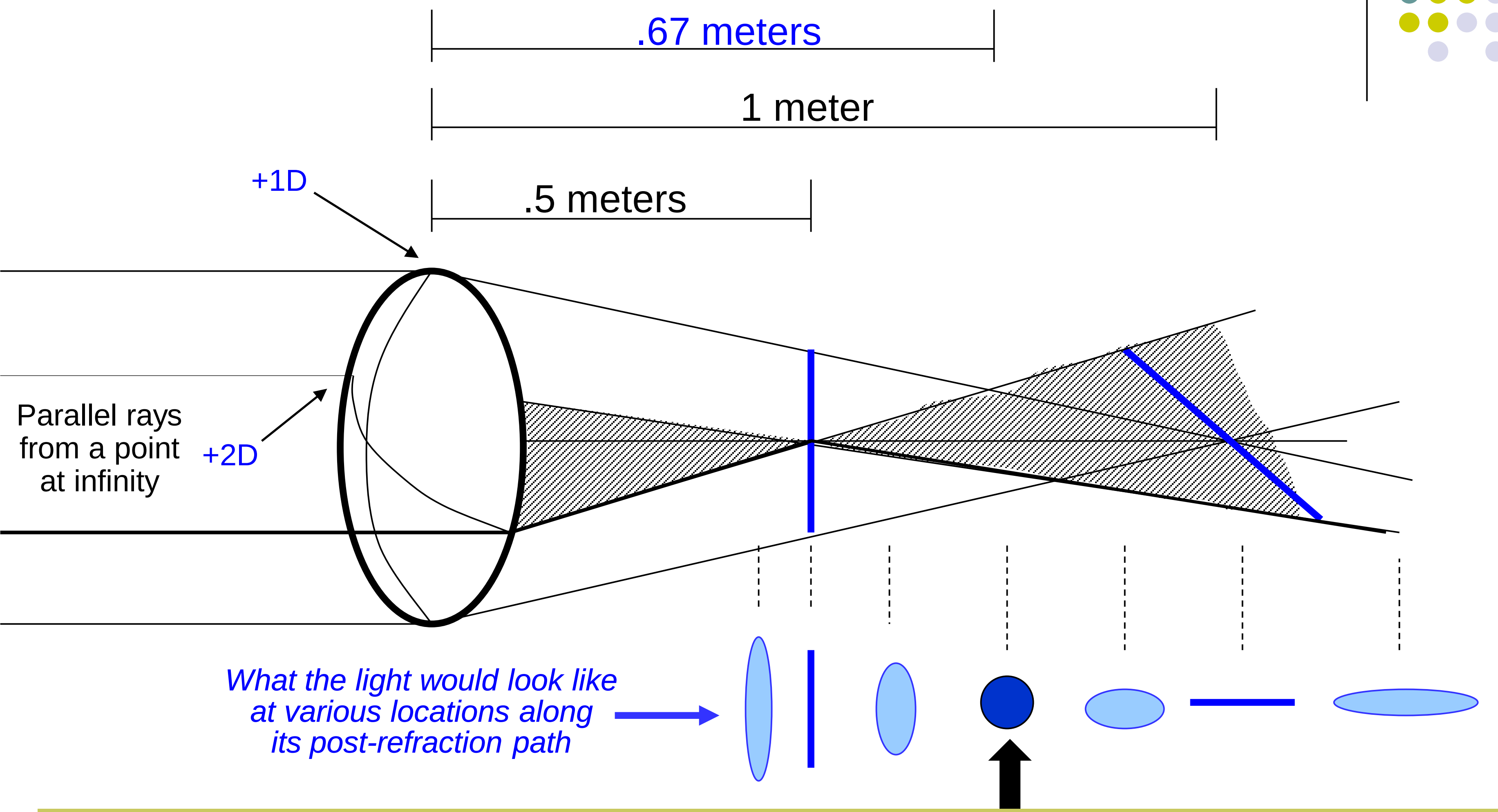
Distance = 1/1.5 = **.67 meters**



What the light would look like at various locations along its post-refraction path

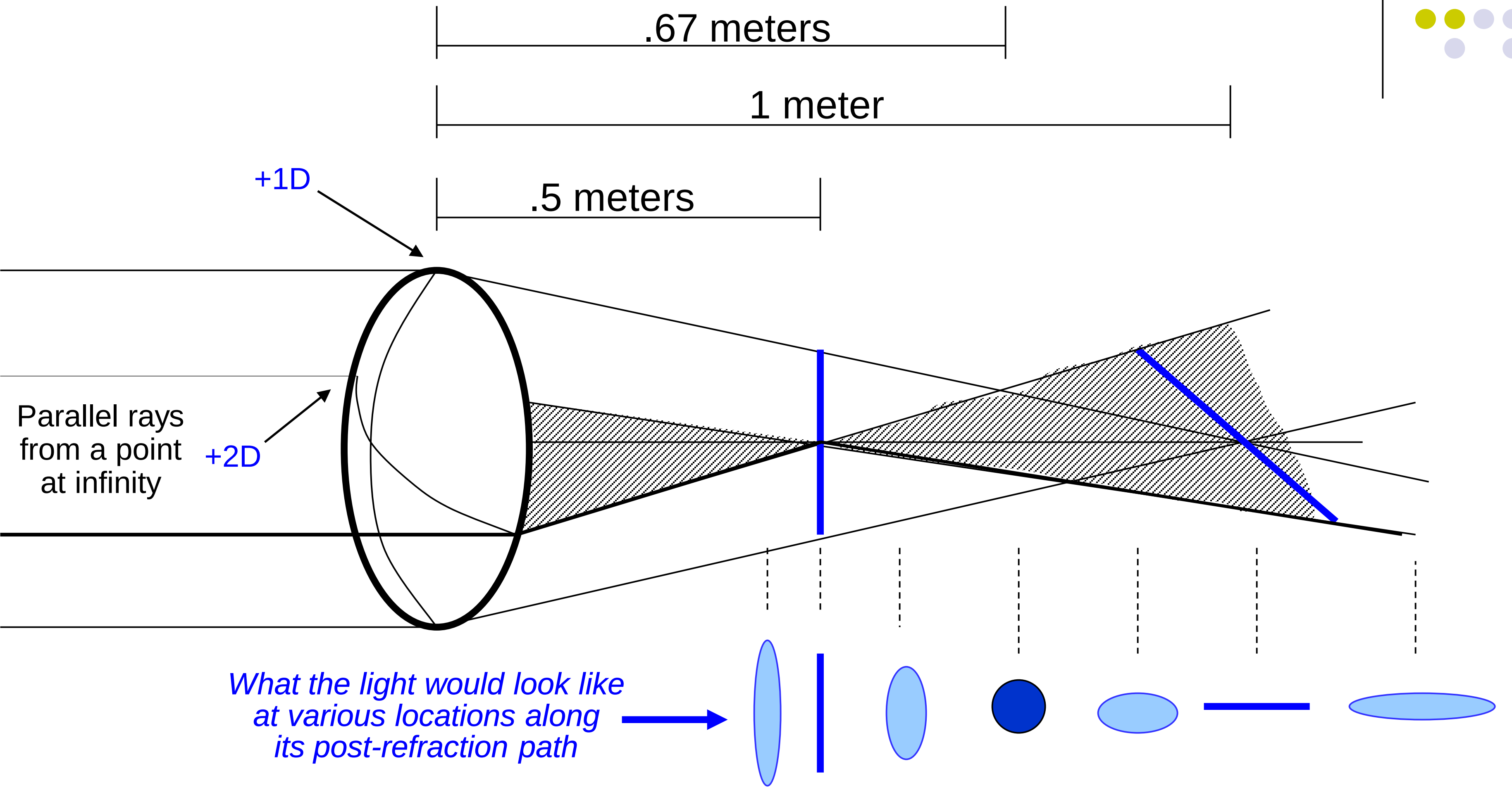
What is the distance from the lens to the circle?
To answer this we first need to determine…
What is the dioptric power associated with the circle?
The dioptric power is the spherical equivalent (S.E.) of the lens--in this case, +1.50D. Therefore, the distance is…

Spherocylindrical Lenses



Note that this circle (about which we will have **much** more to say shortly) is located at the dioptric 'halfway point' between the focal lines (i.e., 1.5 is halfway between 1.0 and 2.0). But be sure to note also that the dioptric halfway point is **not** the same as the **geometric** halfway point (which would be at .75 m in this case).

Spherocylindrical Lenses



So **at last**, we can see now how a spherocylindrical lens focuses parallel rays—not to a single secondary focal point, but rather to a pair of secondary focal **lines** separated by a **circle** of as yet unidentified significance. (To be continued in the next chapter.)