What Goes on Inside a Lens?

What bits are inside a lens?

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What bits are inside a lens?

What do the bits do?

- The optical elements form the image
- The iris determines the aperture …
- … which determines the amount of light let in and the depth of focus
- The other moving parts determine focal length and focus
- The IS components help stabilise the image

What if it's a mirror lens?

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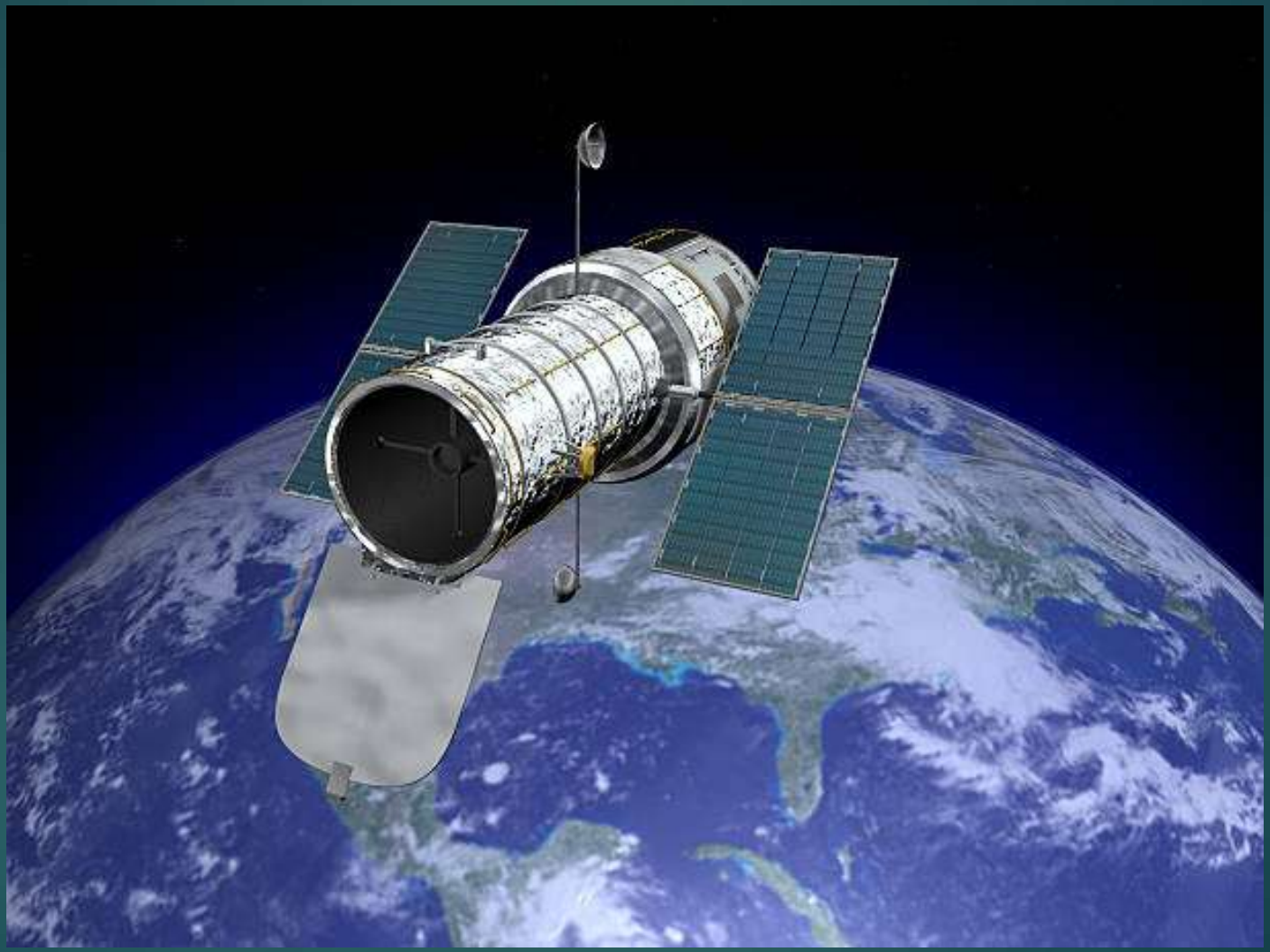
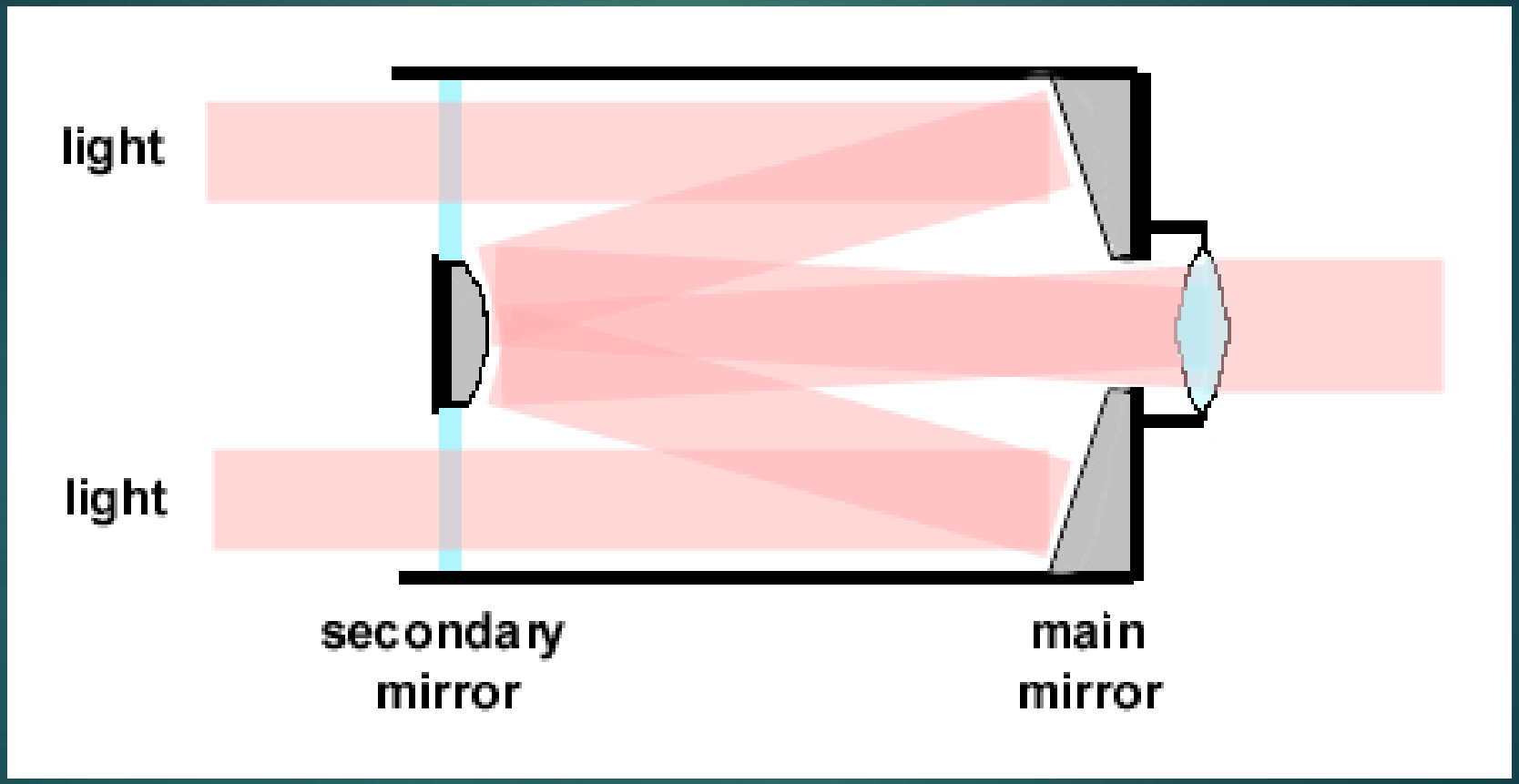
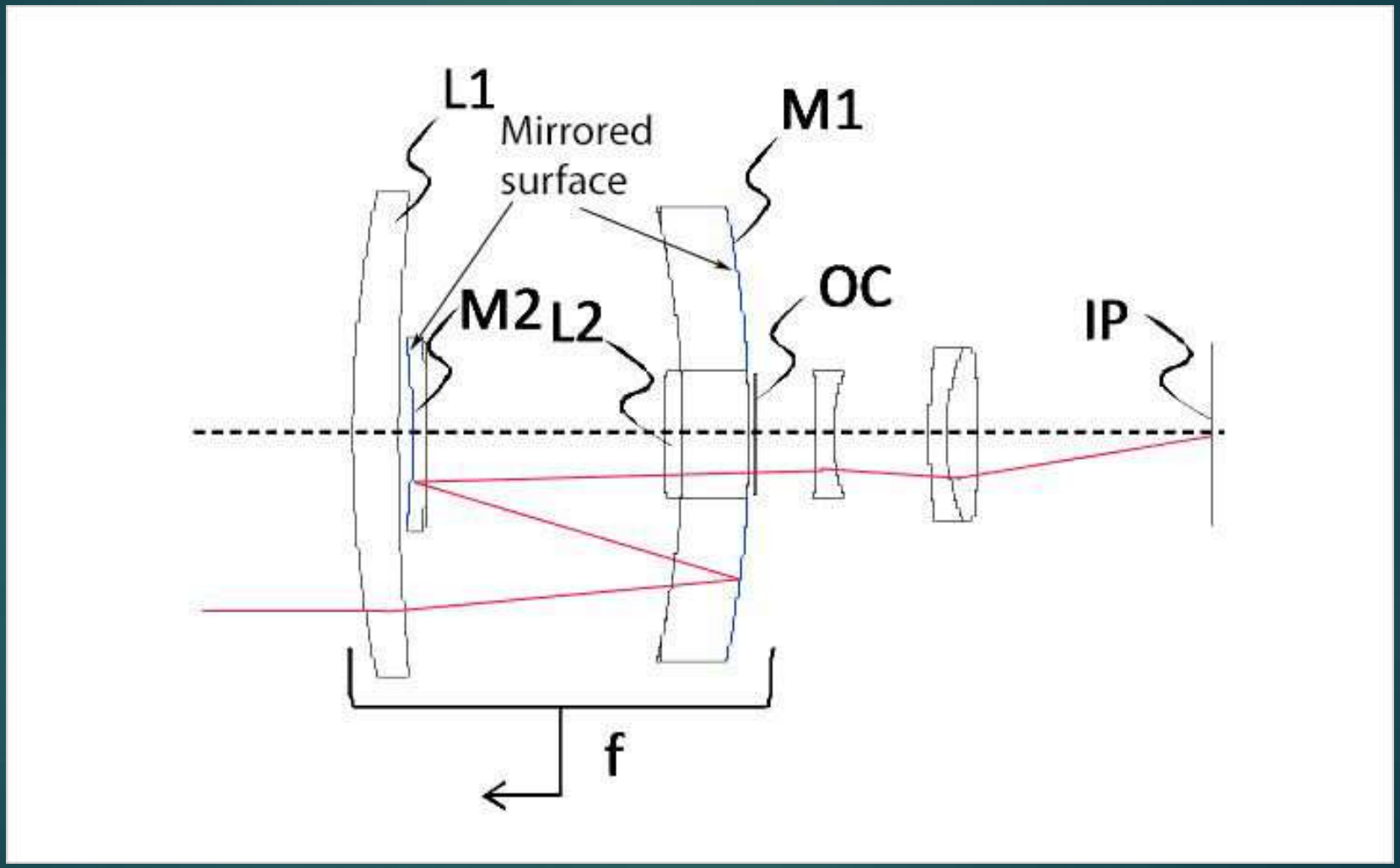


What if it's a mirror lens?



What if it's a mirror lens?

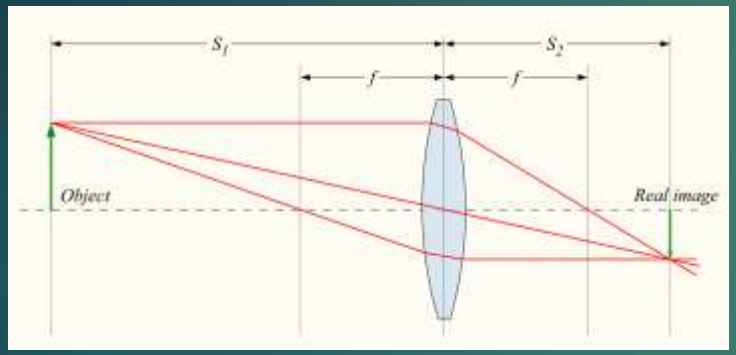


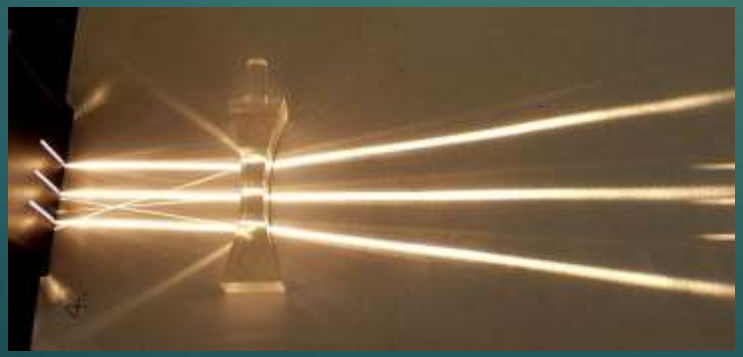
What physics is going on?

- Refraction in the lens elements does the focussing
- Dispersion in the elements causes chromatic aberration
- Diffraction at the edges of the iris degrades sharpness
- Unwanted reflections cause flare
- Interference in the coatings reduce reflections
- The IS sensors are sensing motion …
- … and adjusting elements to correct

What physics is going on?

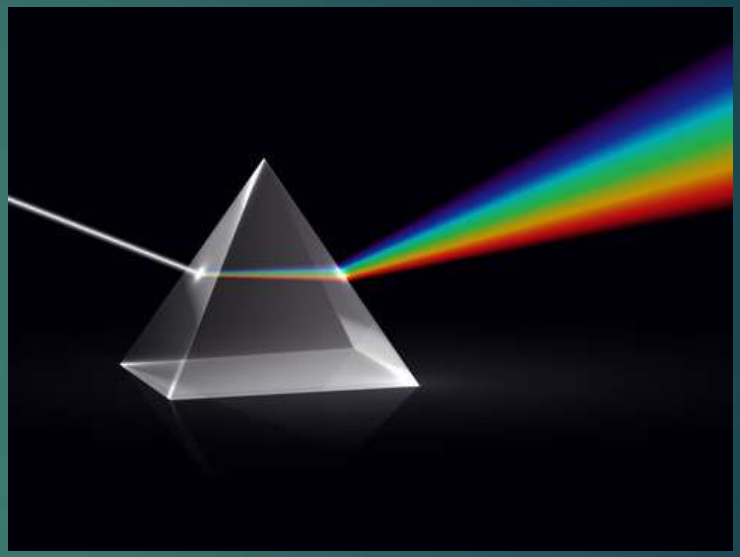
- Refraction

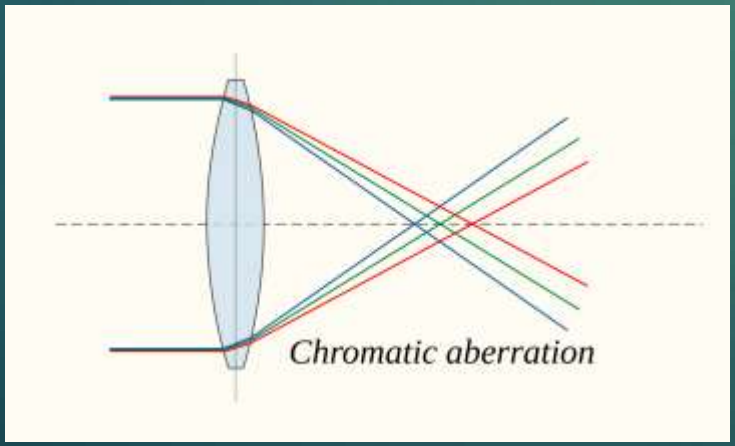




What physics is going on?

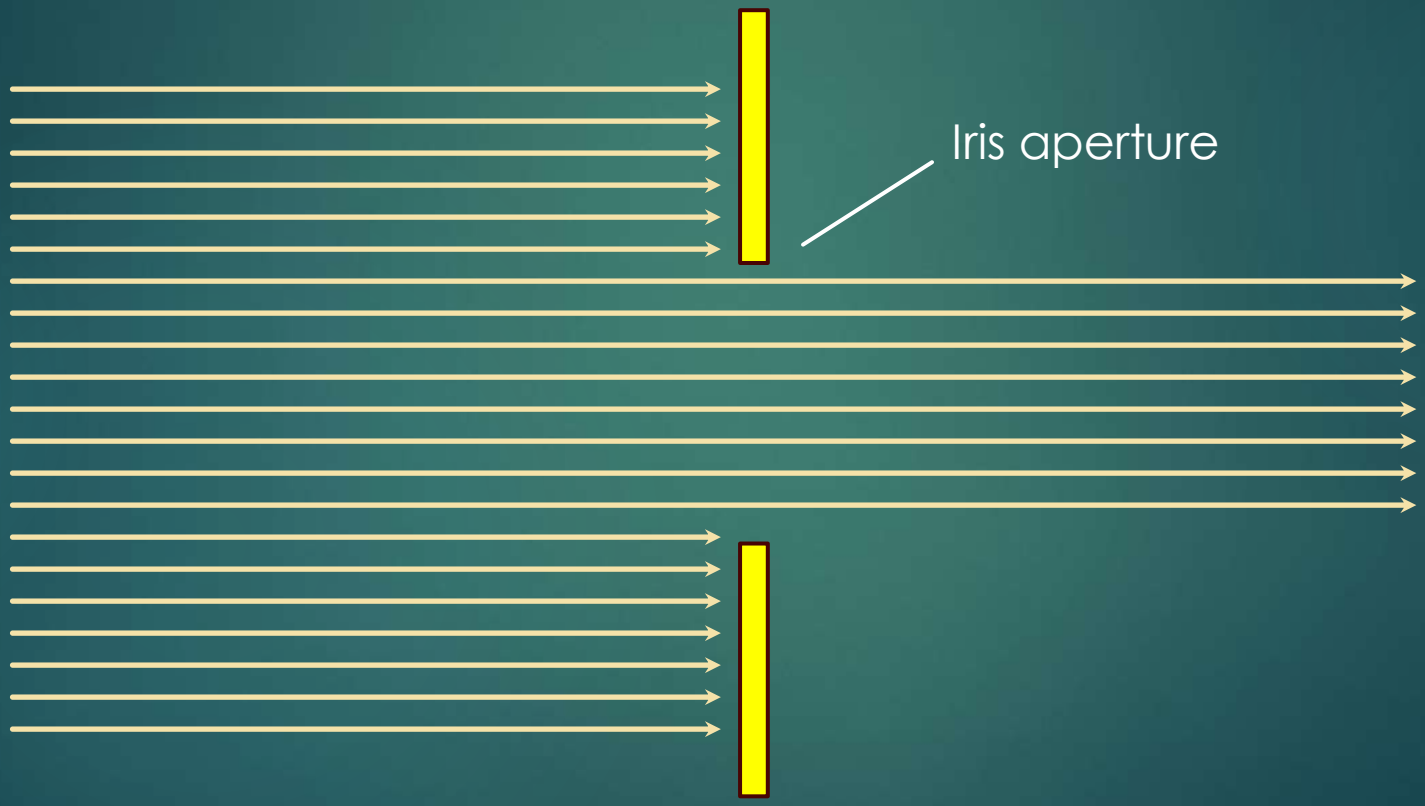
- Dispersion →





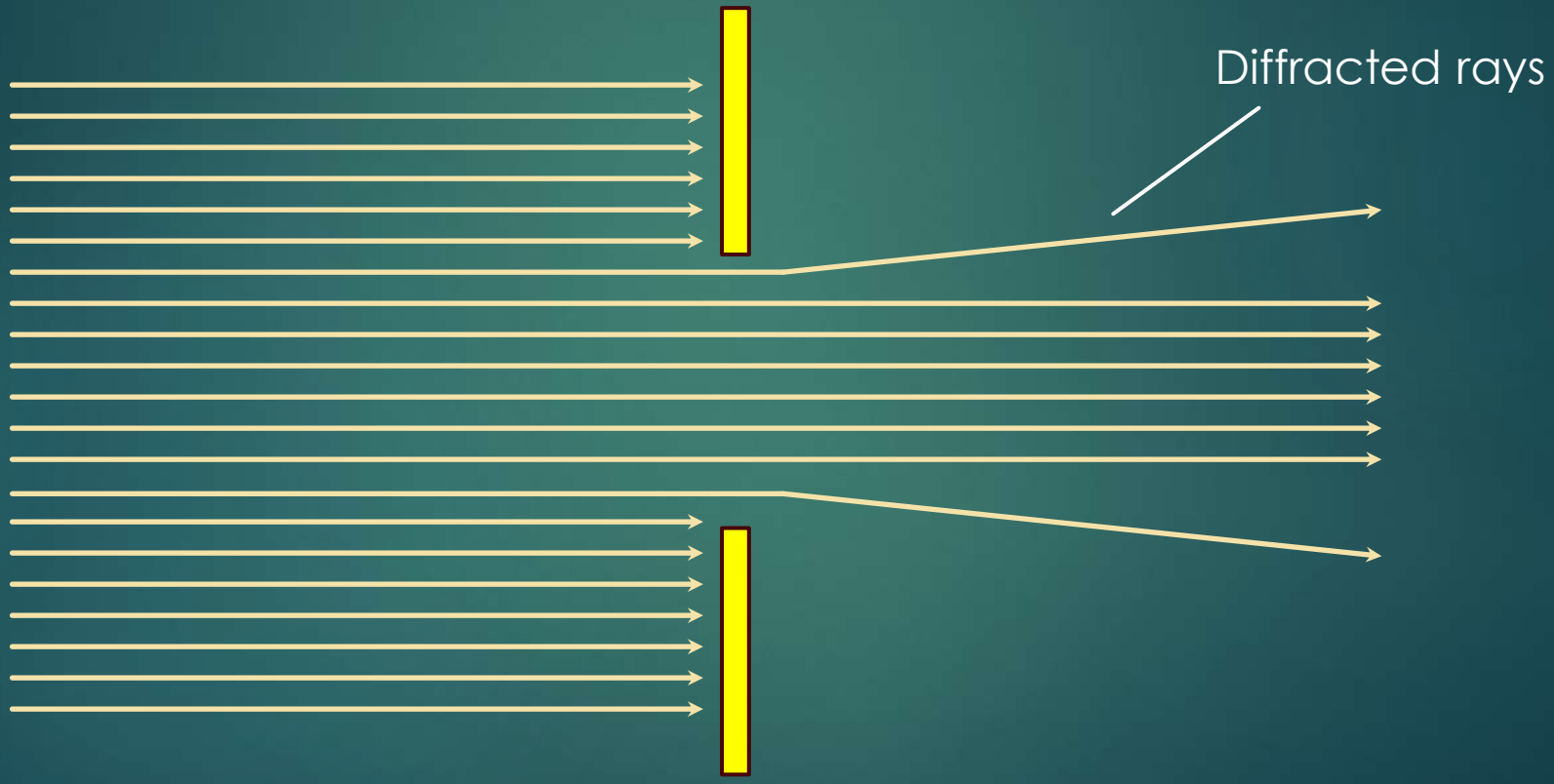
What physics is going on?

- Diffraction



What physics is going on?

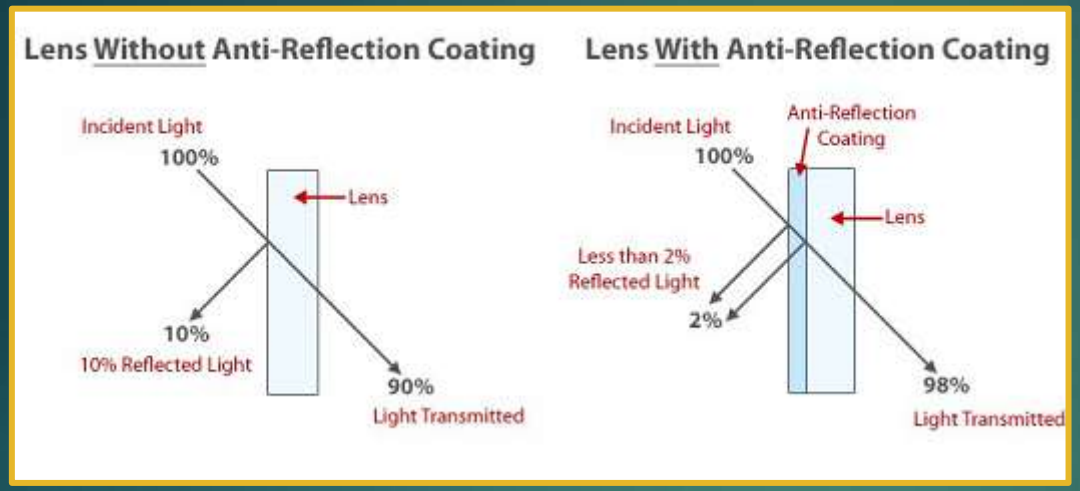
- Diffraction



What physics is going on?

- Unwanted reflections

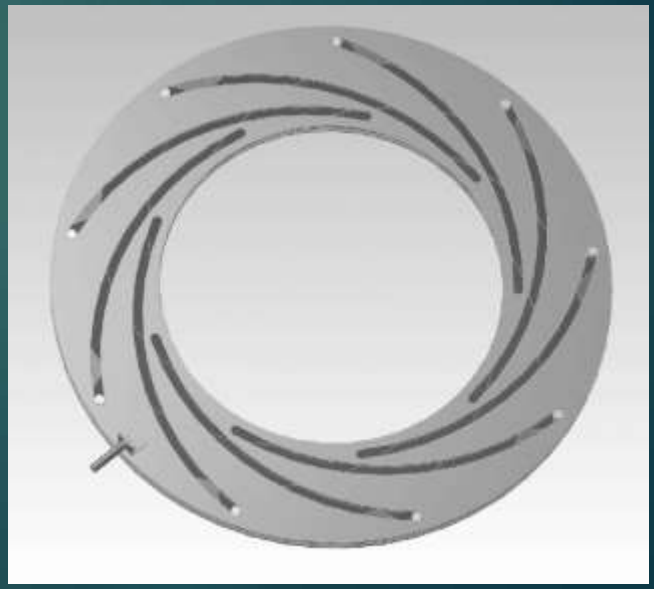
What physics is going on?



What physics is going on?

Aperture and sharpness

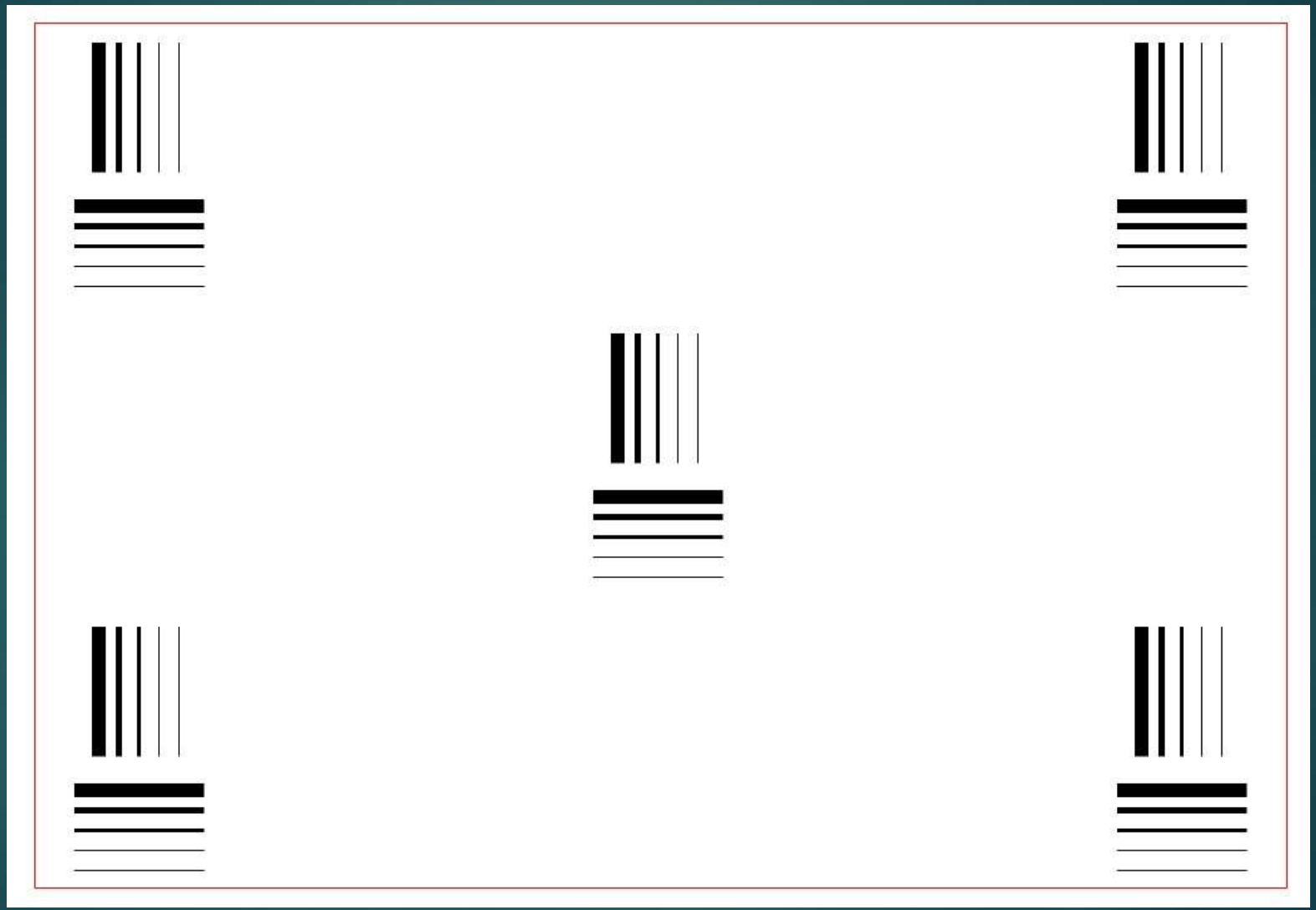
- The aperture to which the iris is set determines light received and the depth of focus
- The f number tells us the aperture
- Every doubling of the f number means a quarter of the aperture area
- So f/8 means two stops less light than f/4



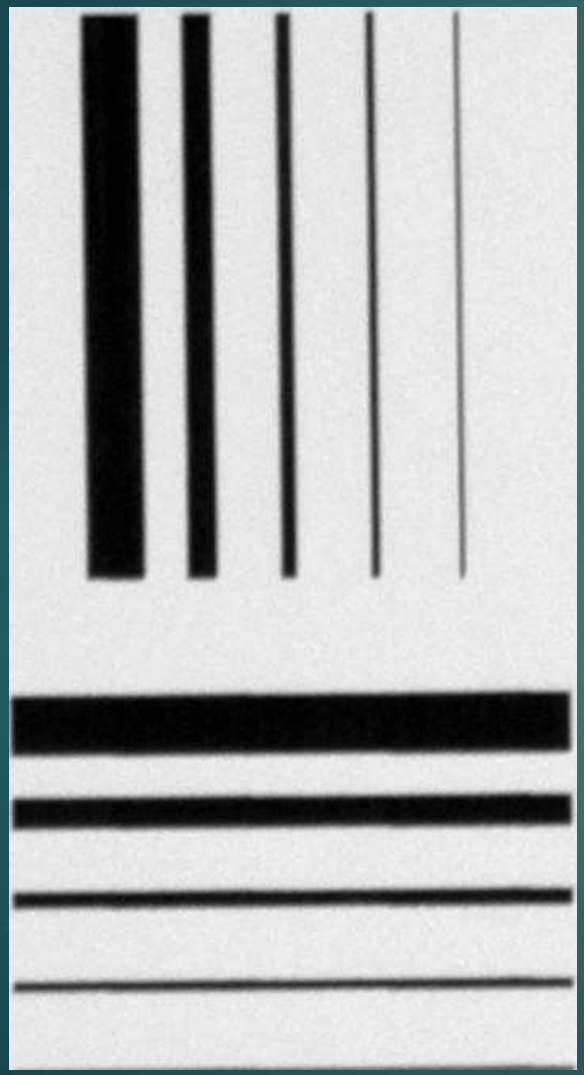
Aperture and sharpness

- Why does a small aperture mean more depth of focus?
  - In the limit of a pinhole camera, everything would be in focus
- Why don’t we see the shape of the iris?
  - Sometimes we do!

A simple test card



A simple test card - results

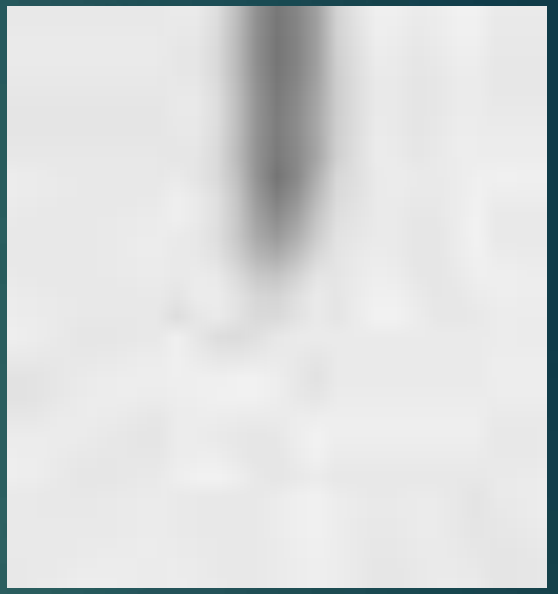


EF 70 – 300 mm lens

115 mm focal length

f/4.5

Top-left



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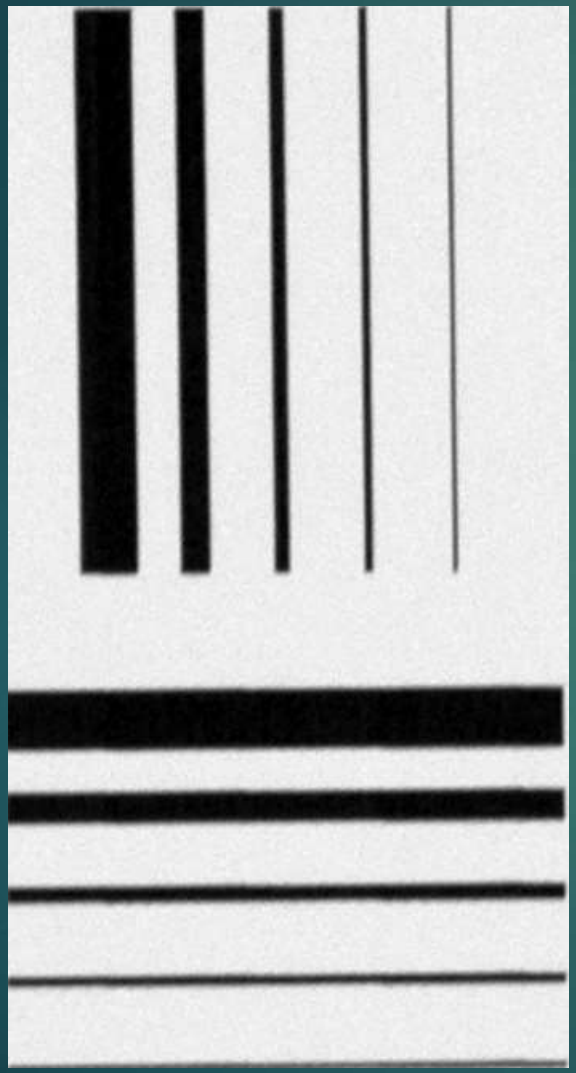
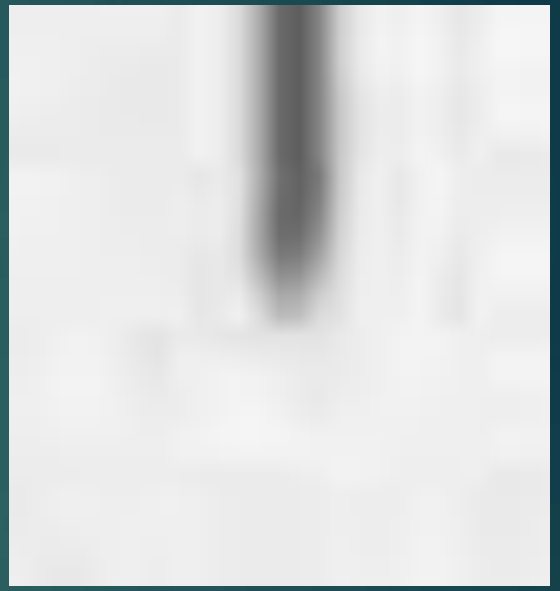


EF 70 – 300 mm lens

115 mm focal length

f/6.3

Top-left



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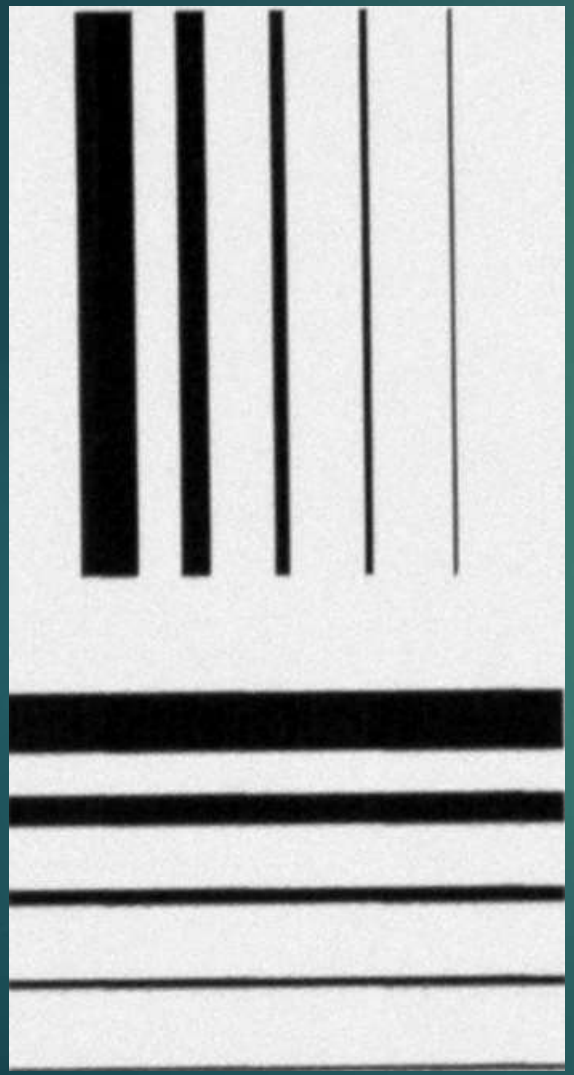
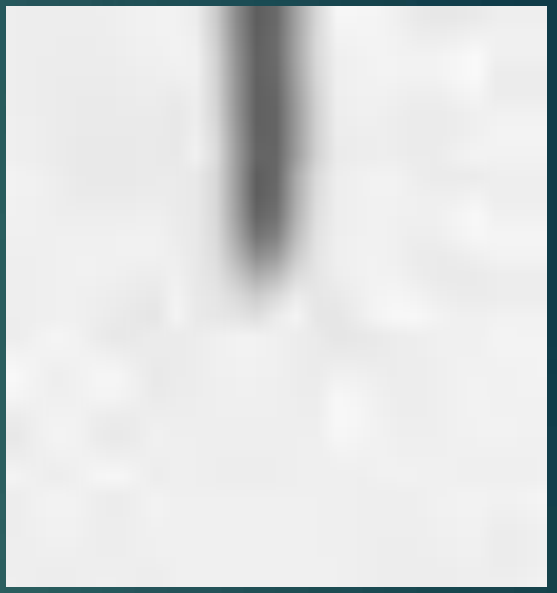


EF 70 – 300 mm lens

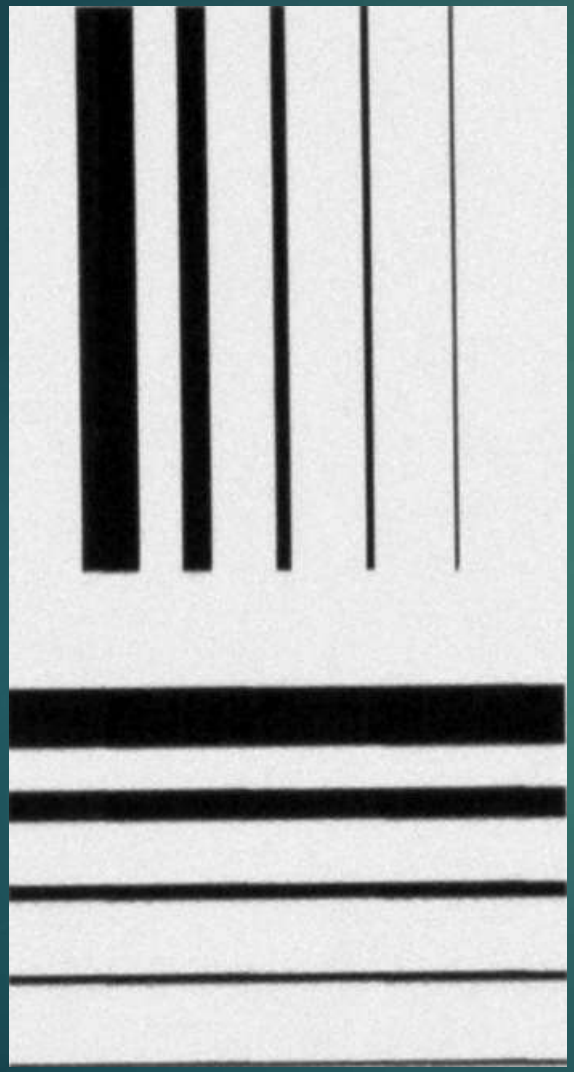
115 mm focal length

f/9

Top-left



A simple test card - results

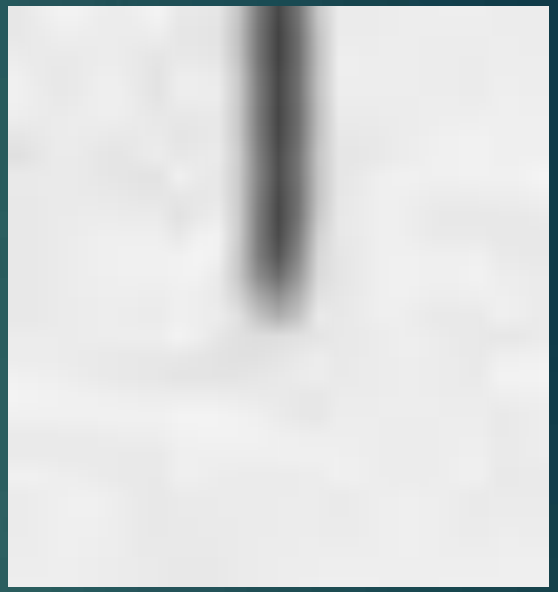


EF 70 – 300 mm lens

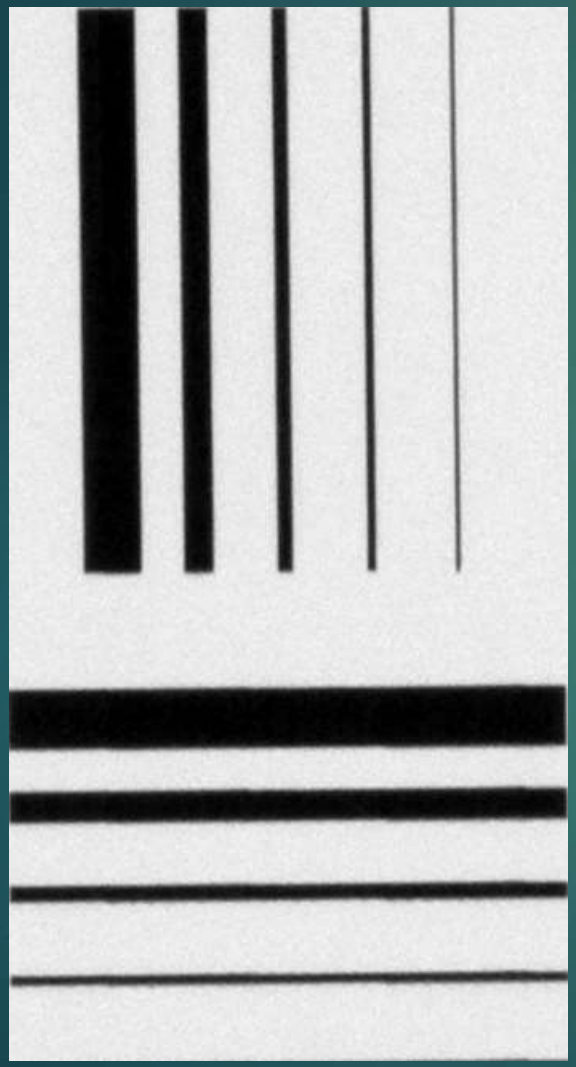
115 mm focal length

f/13

Top-left



A simple test card - results

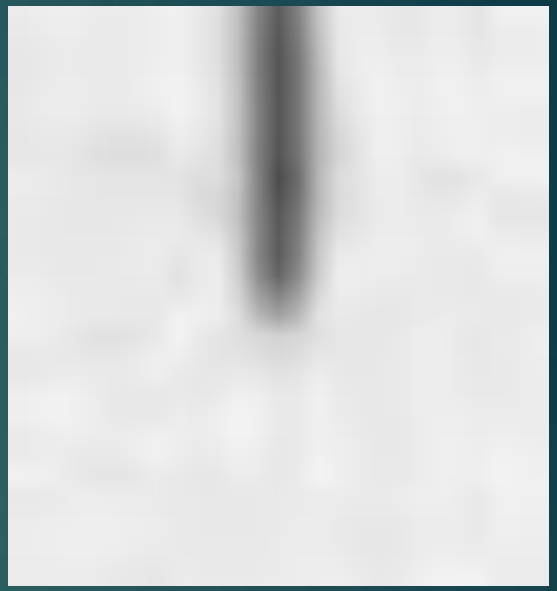


EF 70 – 300 mm lens

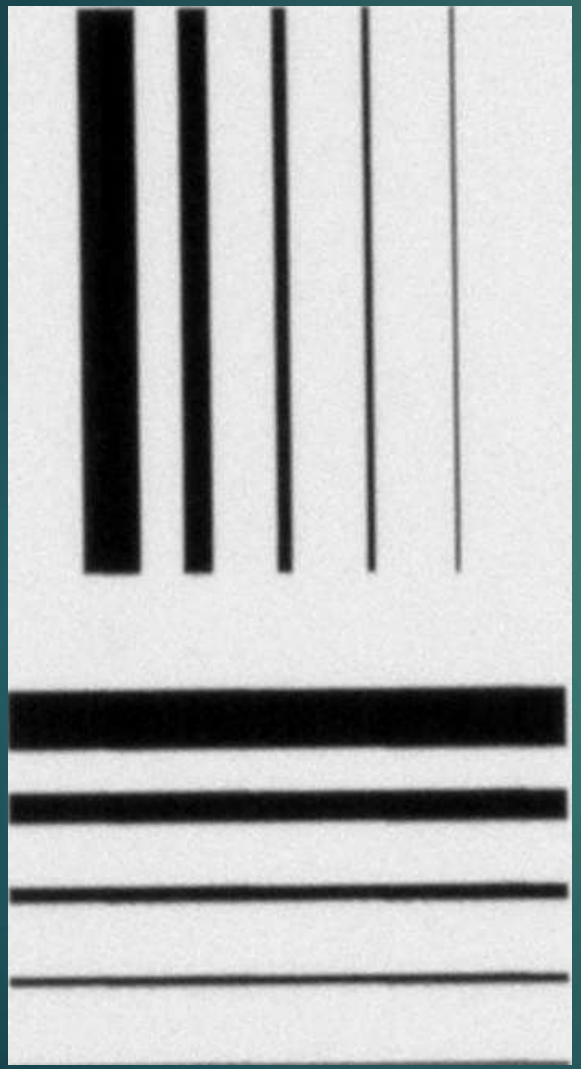
115 mm focal length

f/18

Top-left



A simple test card - results

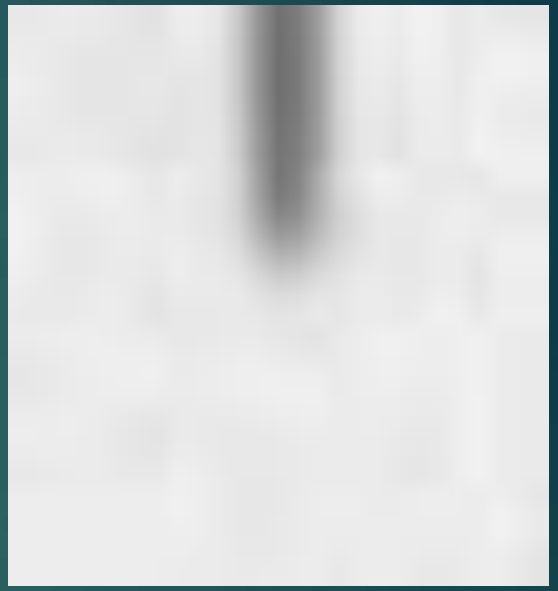


EF 70 – 300 mm lens

115 mm focal length

f/25

Top-left



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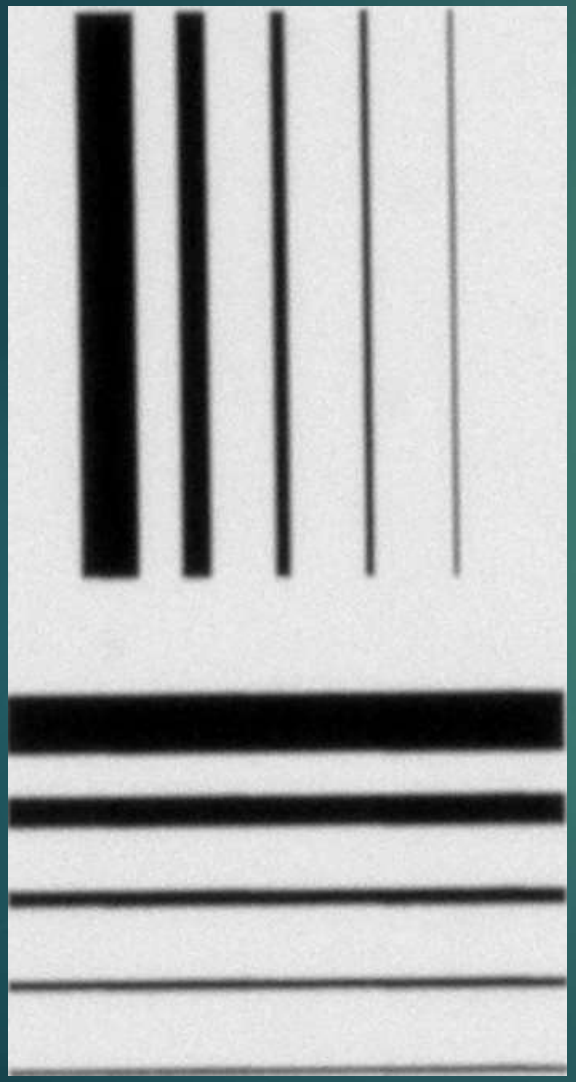
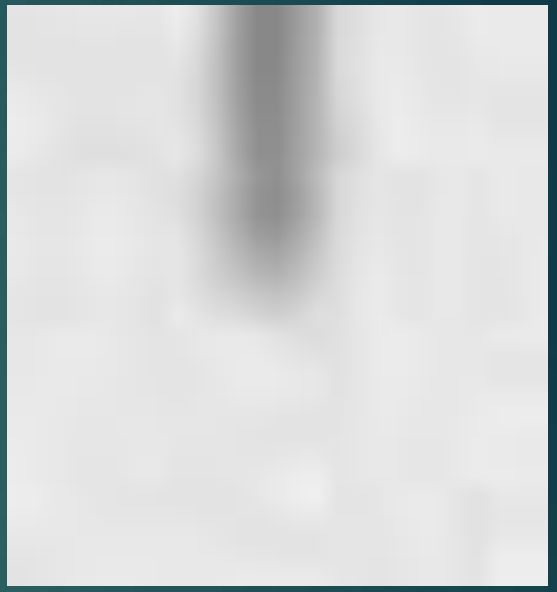


EF 70 – 300 mm lens

115 mm focal length

f/36

Top-left



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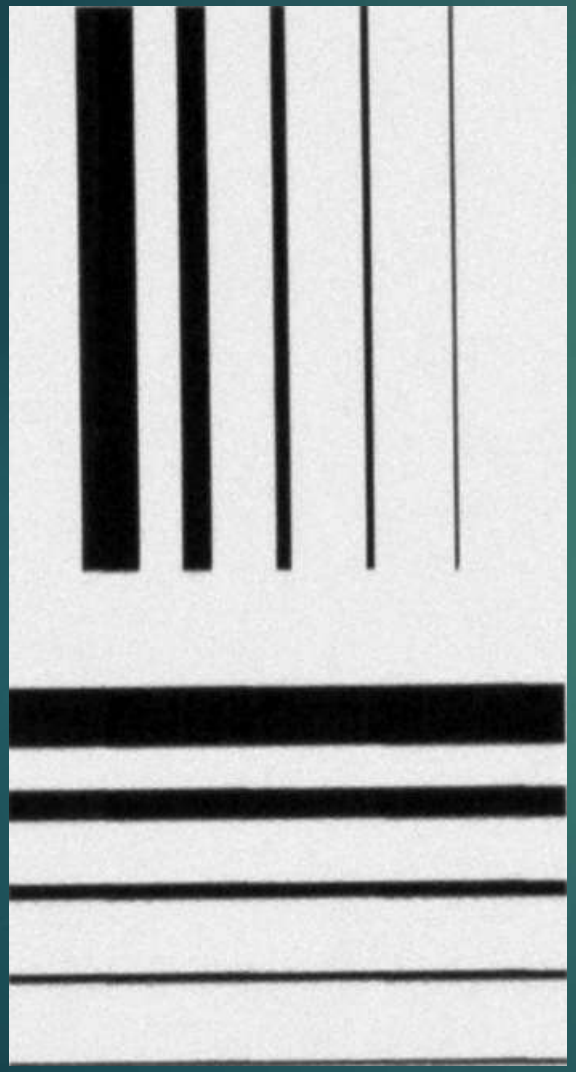
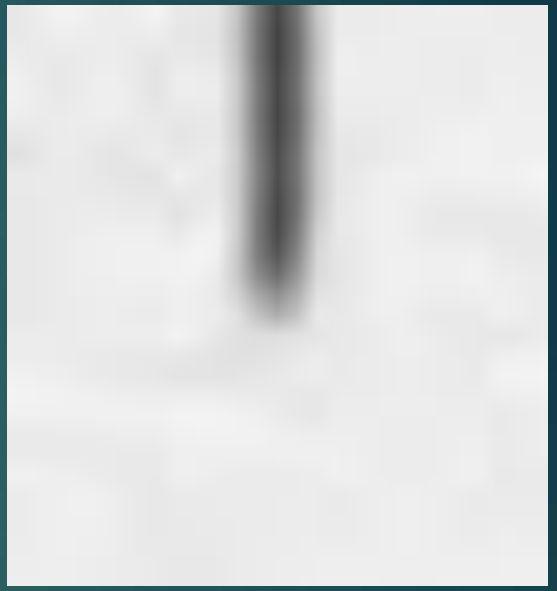


EF 70 – 300 mm lens

115 mm focal length

f/13

Top-left



A macro case study

A macro case study

- Depth of focus is a major image for macro images …
- … hence the ring flash on the previous slide

A macro case study

f/4, 1/64 ring flash power

A macro case study

f/5.6, 1/32 ring flash power

A macro case study

f/8, 1/16 ring flash power

A macro case study

f/11, 1/8 ring flash power

A macro case study

f/16, 1/4 ring flash power

A macro case study

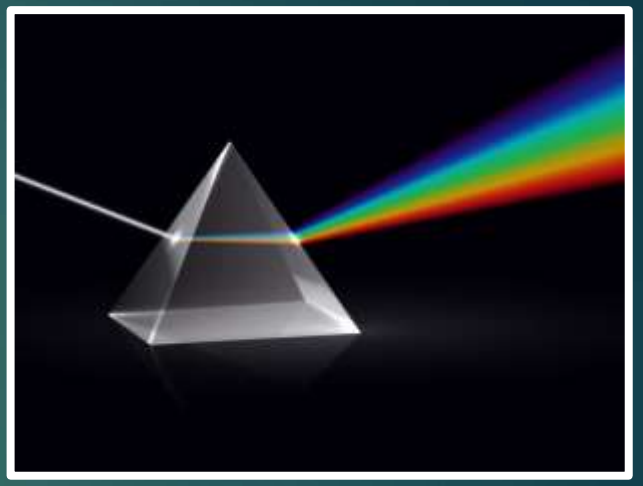
f/22, 1/2 ring flash power

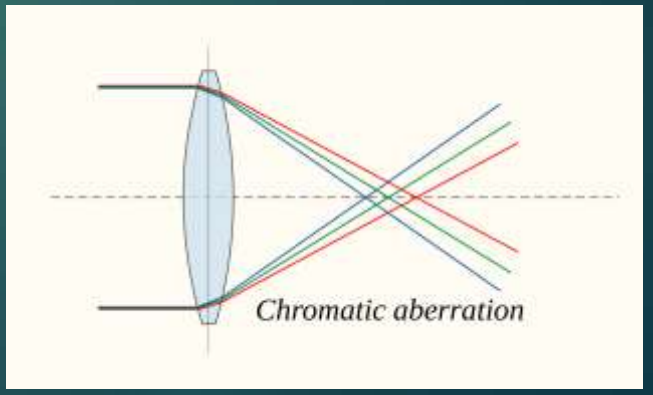
A macro case study

f/32, full ring flash power

Chromatic aberration

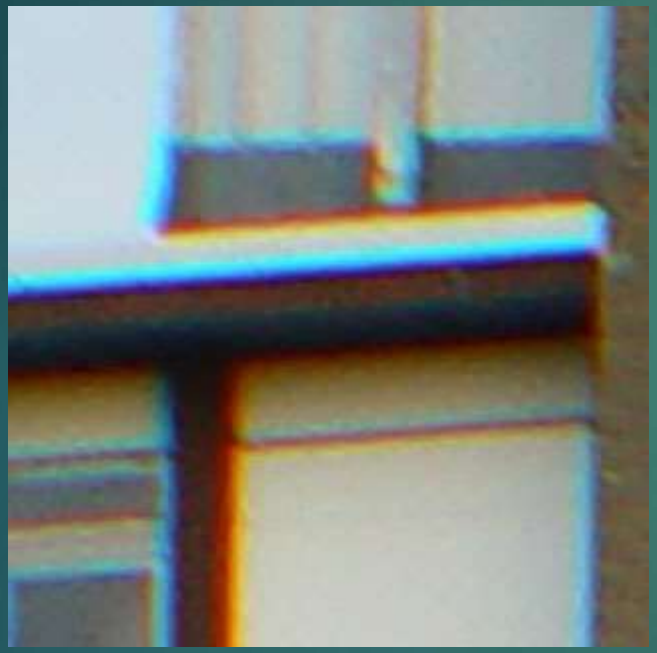
- Chromatic aberration results from the failure of a lens to bring all colours to the same focus
- The is a consequence of dispersion

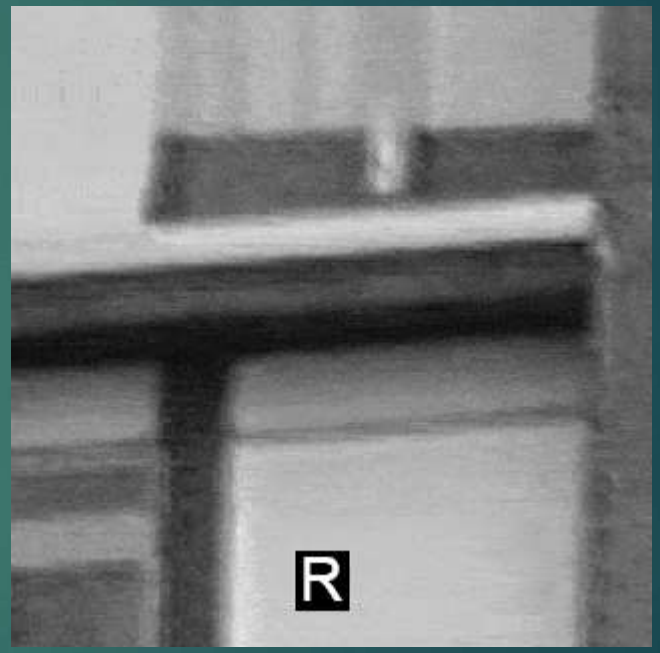




Chromatic aberration

Chromatic aberration





Chromatic aberration

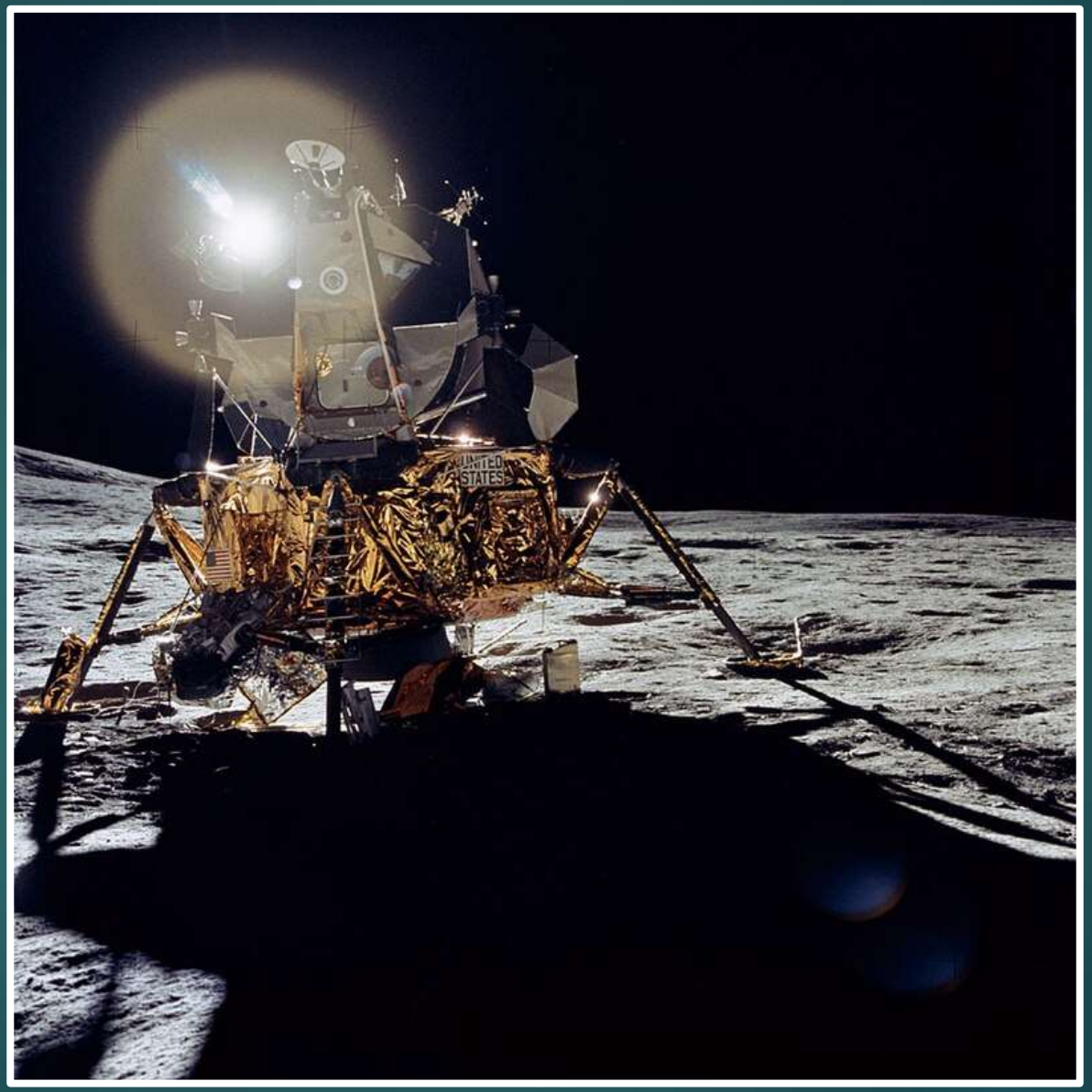
- Chromatic aberration can be corrected automatically by Lightroom and other tools using manufacturer's lens data
- It can also be corrected by such tools (presumably less well) without that data (please don't ask how)

Flare

- Flare results from unwanted reflections within a lens from lens element surfaces
- It manifests itself as unwanted shapes and lines within an image
- The light which gets (unwanted) reflection may not even come from the scene being photographed!

Flare

Flare



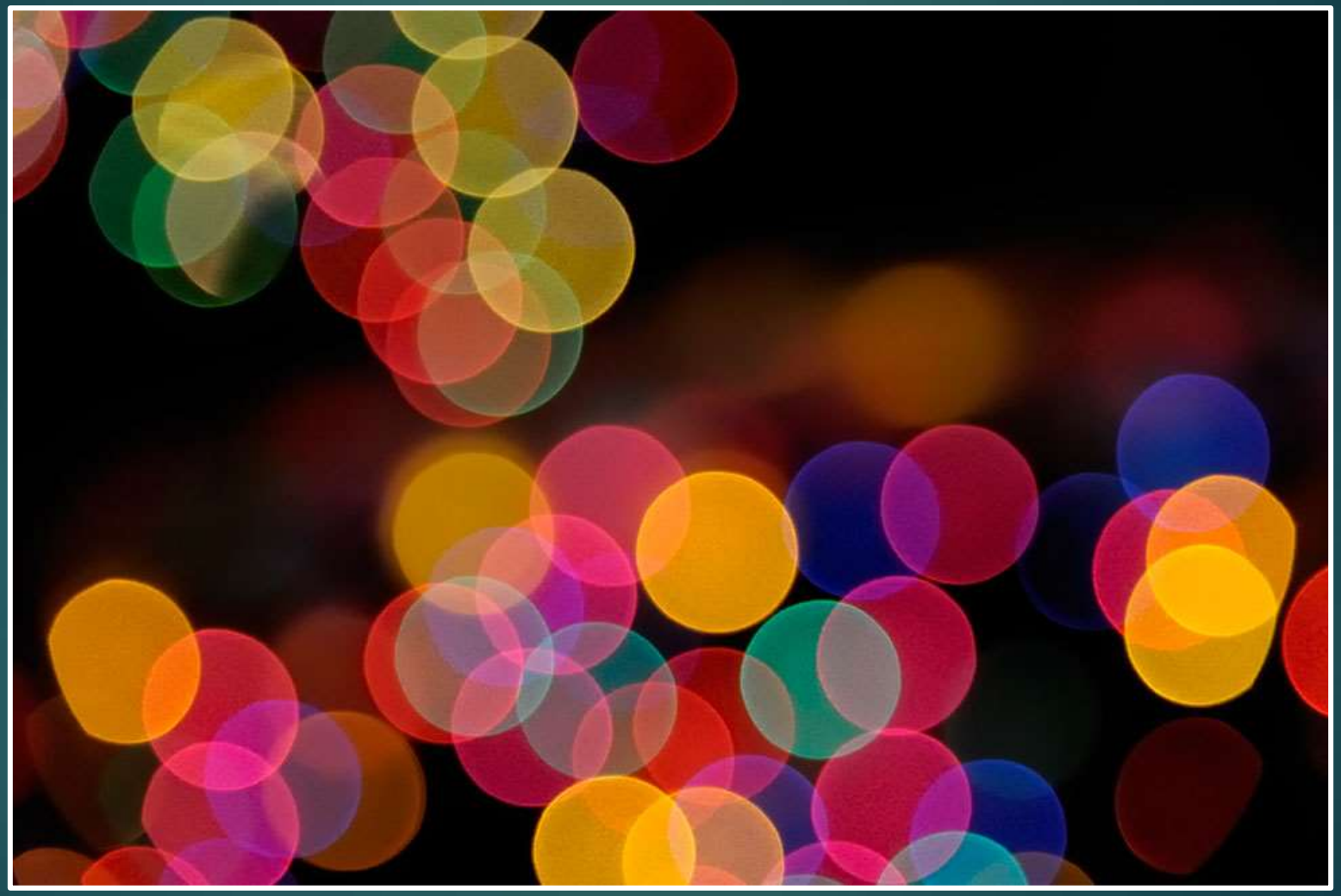
Flare

Flare

Bokeh

- Bokeh is the name given to out-of-focus highlights
- The shape of bokeh is determined by the shape and size of the aperture
- In a sense, each bit of bokeh is an out-of-focus image of the iris
- Shaped bokeh can be produced by a mask over the lens
- ‘Swirly’ bokeh can be produced by particular lenses

Bokeh



Bokeh

Bokeh

Bokeh

Bokeh

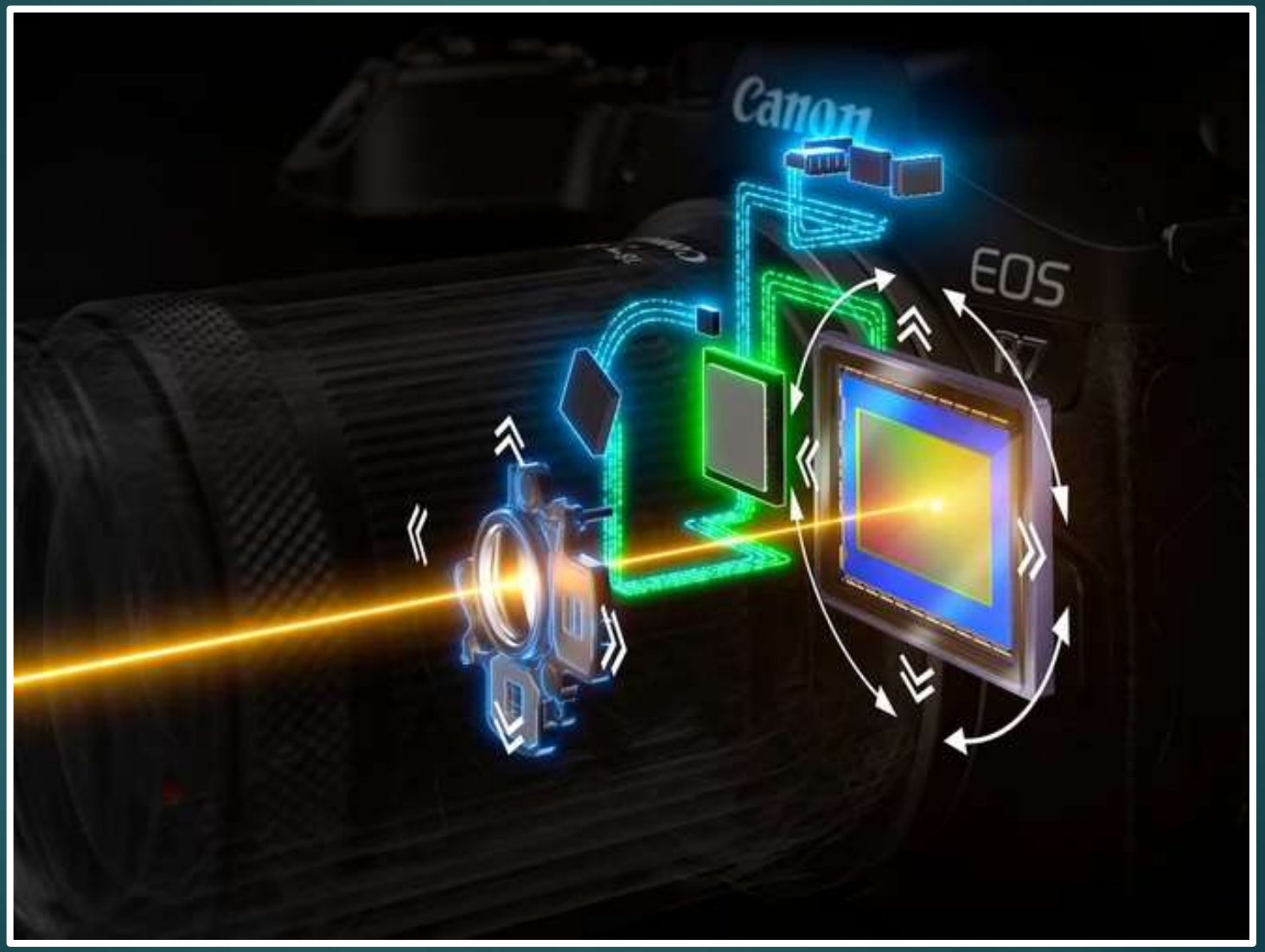
Bokeh

What is image stabilisation?

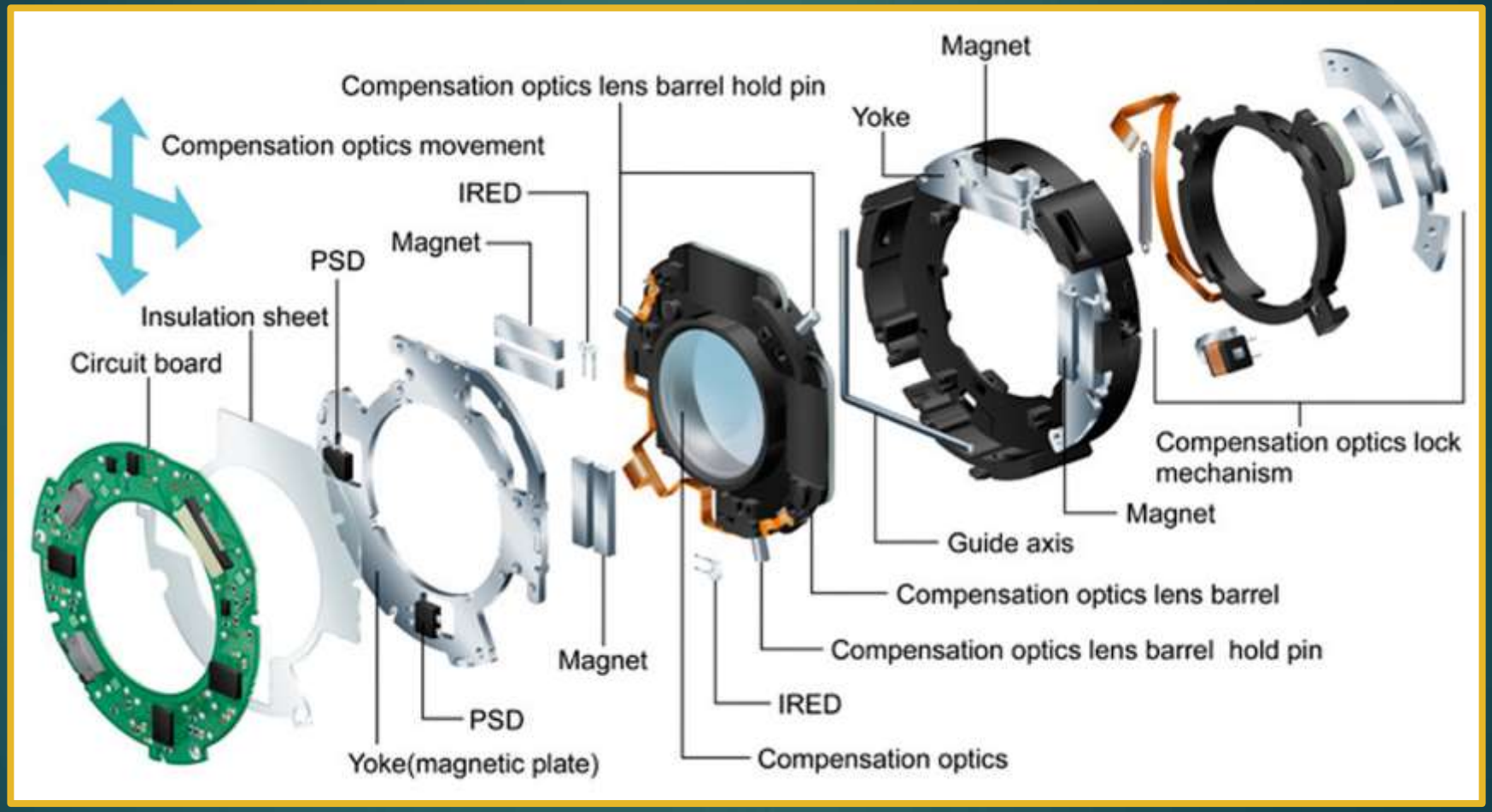
- Image stabilisation aims to combat camera shake
- Typically, IS allows shutter speeds 2 or 3 stops slower
- Several approaches are possible – some purely digital
- The ‘normal approach’ involves sensors and ‘floating elements’ within the lens
- The sensors detect the camera shake, and the camera’s electronics feeds currents to the floating elements to correct for the motion

How good is IS?

How does IS work?



How does IS work?

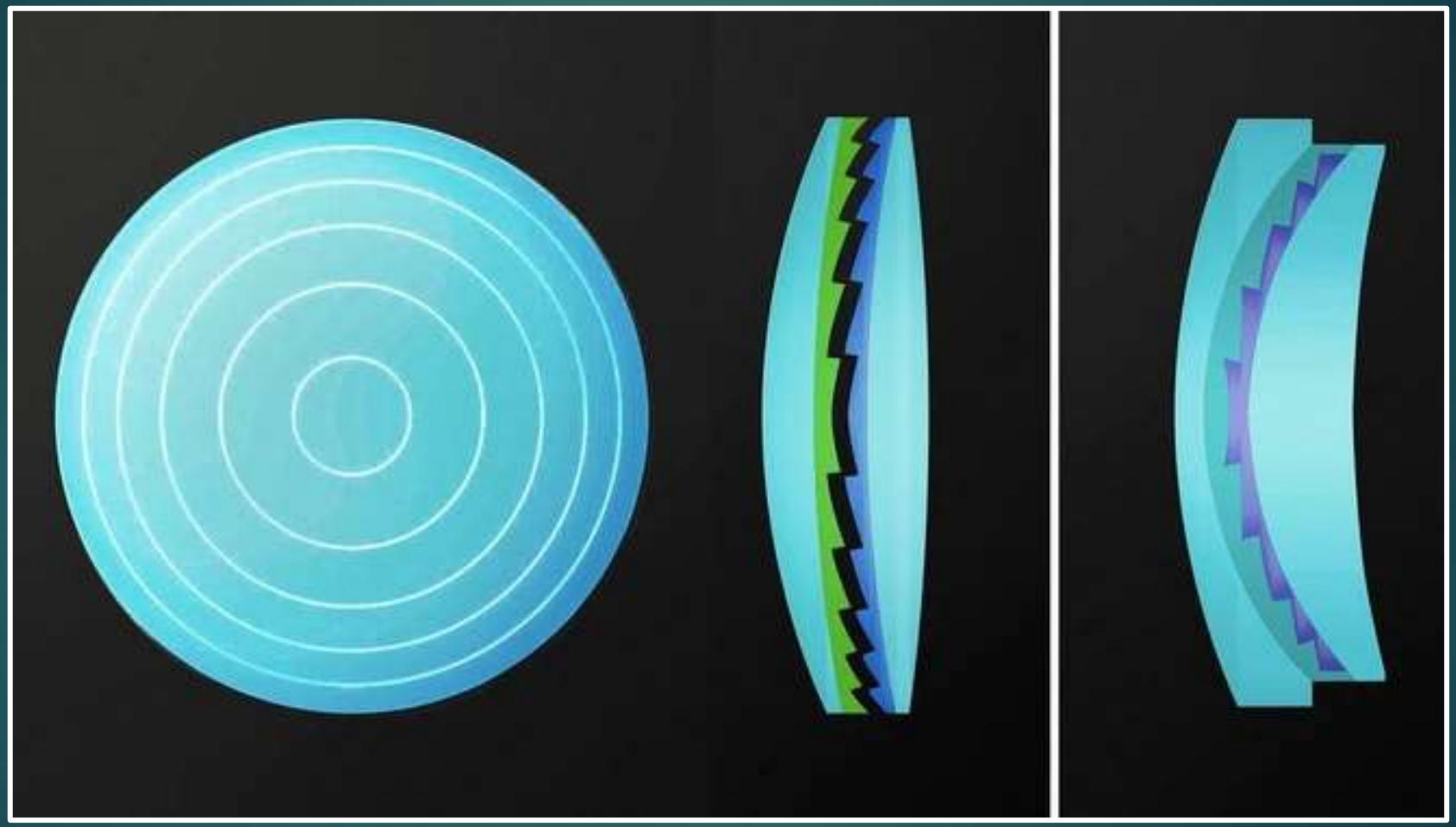


How does IS work?

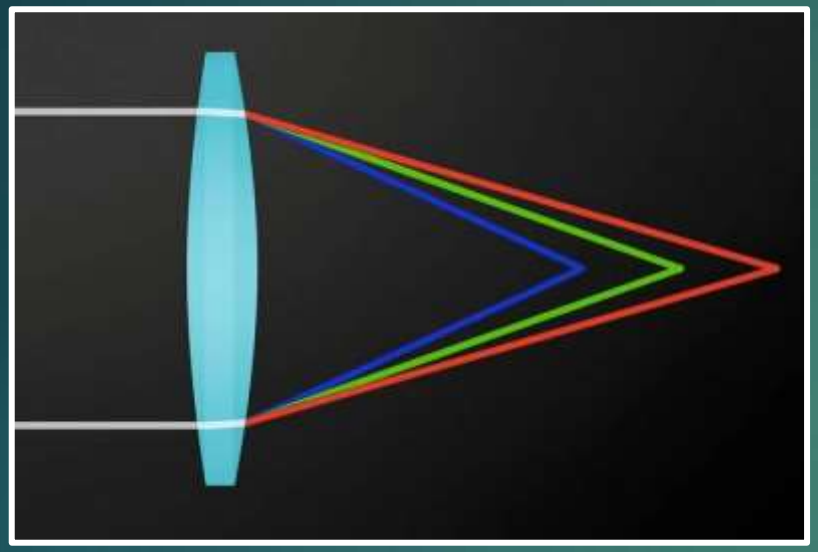
Diffractive elements

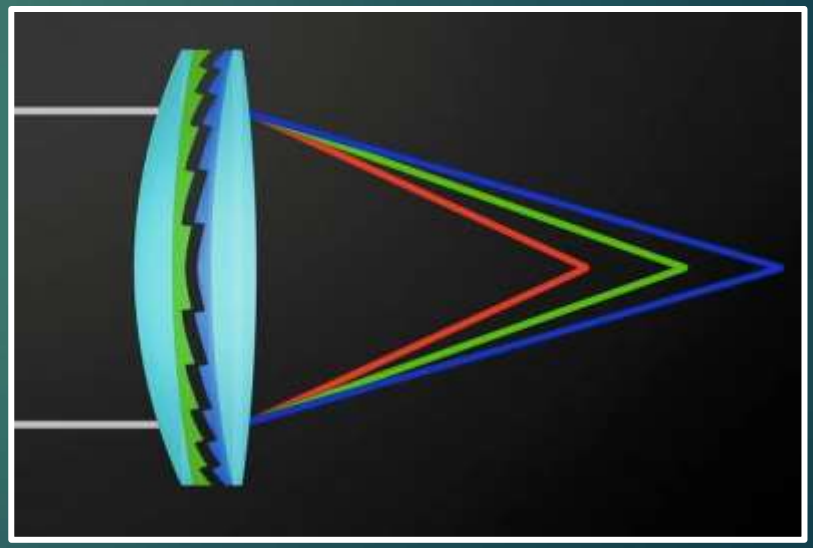
- Diffraction can be built into a lens element by machining circular ‘steps’ into its surface
- The circles need to be closely spaced – comparable with a wavelength of light
- There are advantages to diffractive elements (DO in Canon terminology) when combatting CA
- Basically, the CA properties of a ‘conventional’ elements can be cancelled by using a DO element

Diffractive elements

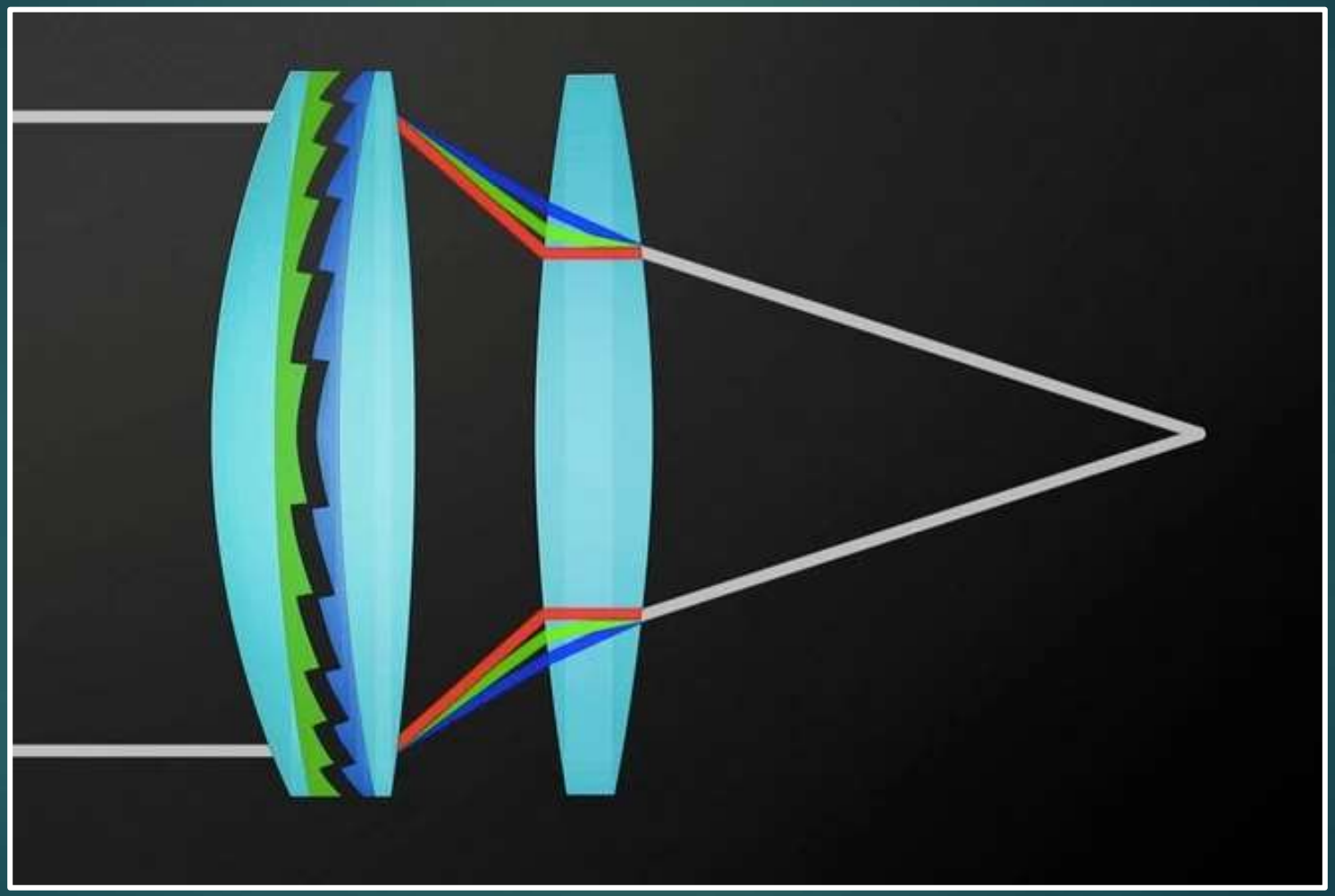


Diffractive elements





Diffractive elements



THE END!