

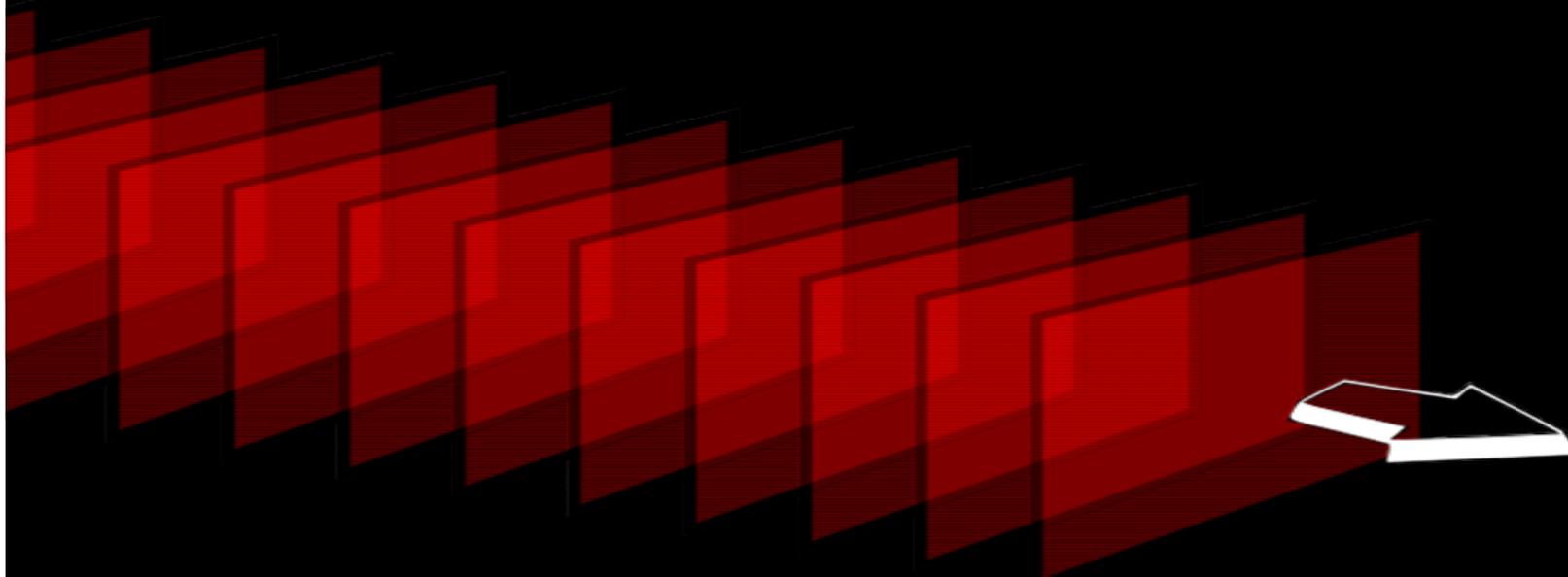
# A REVIEW OF ABERROMETRY

Francesco Versaci

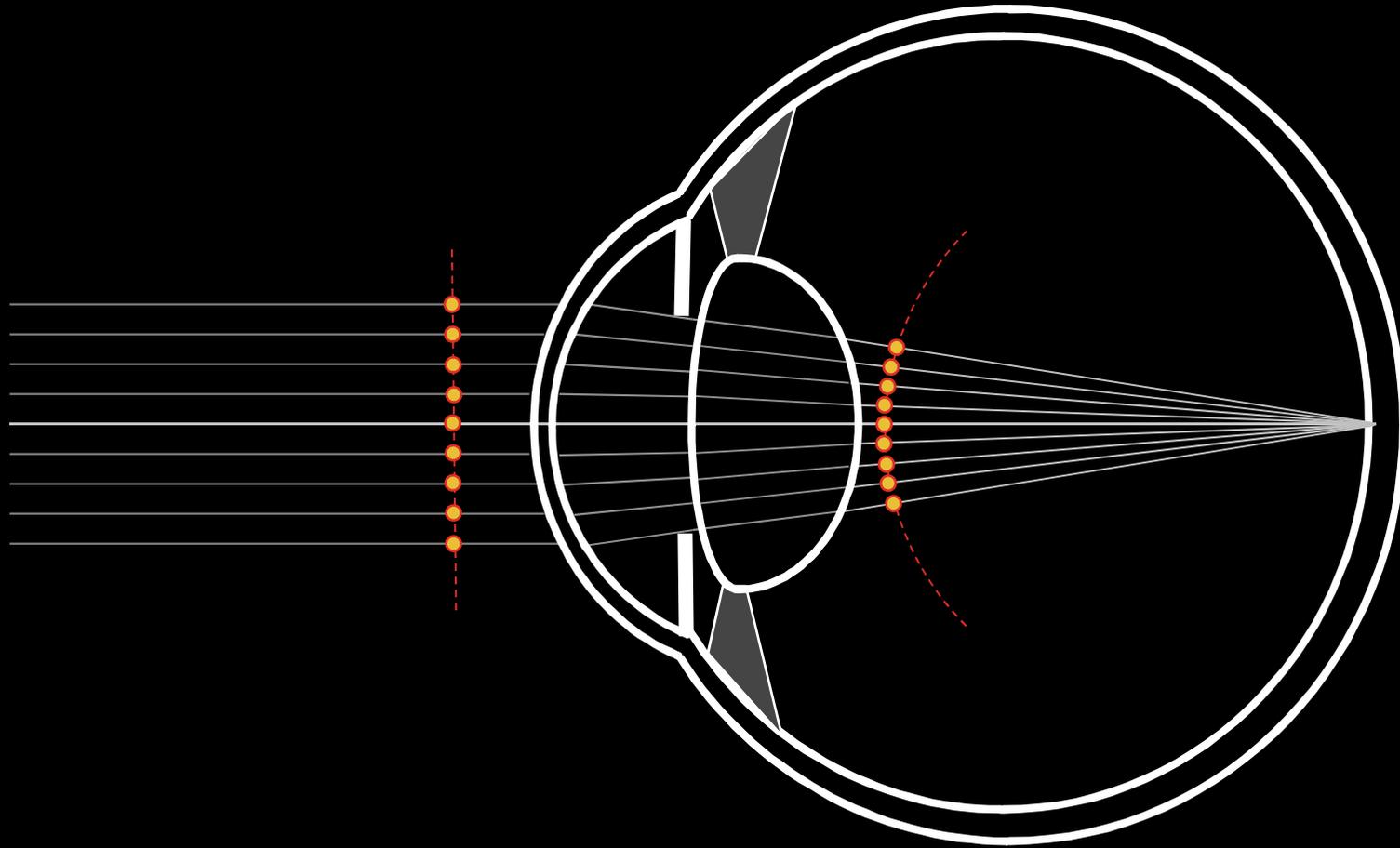
# WAVEFRONT

## WHAT IS THE WAVEFRONT?

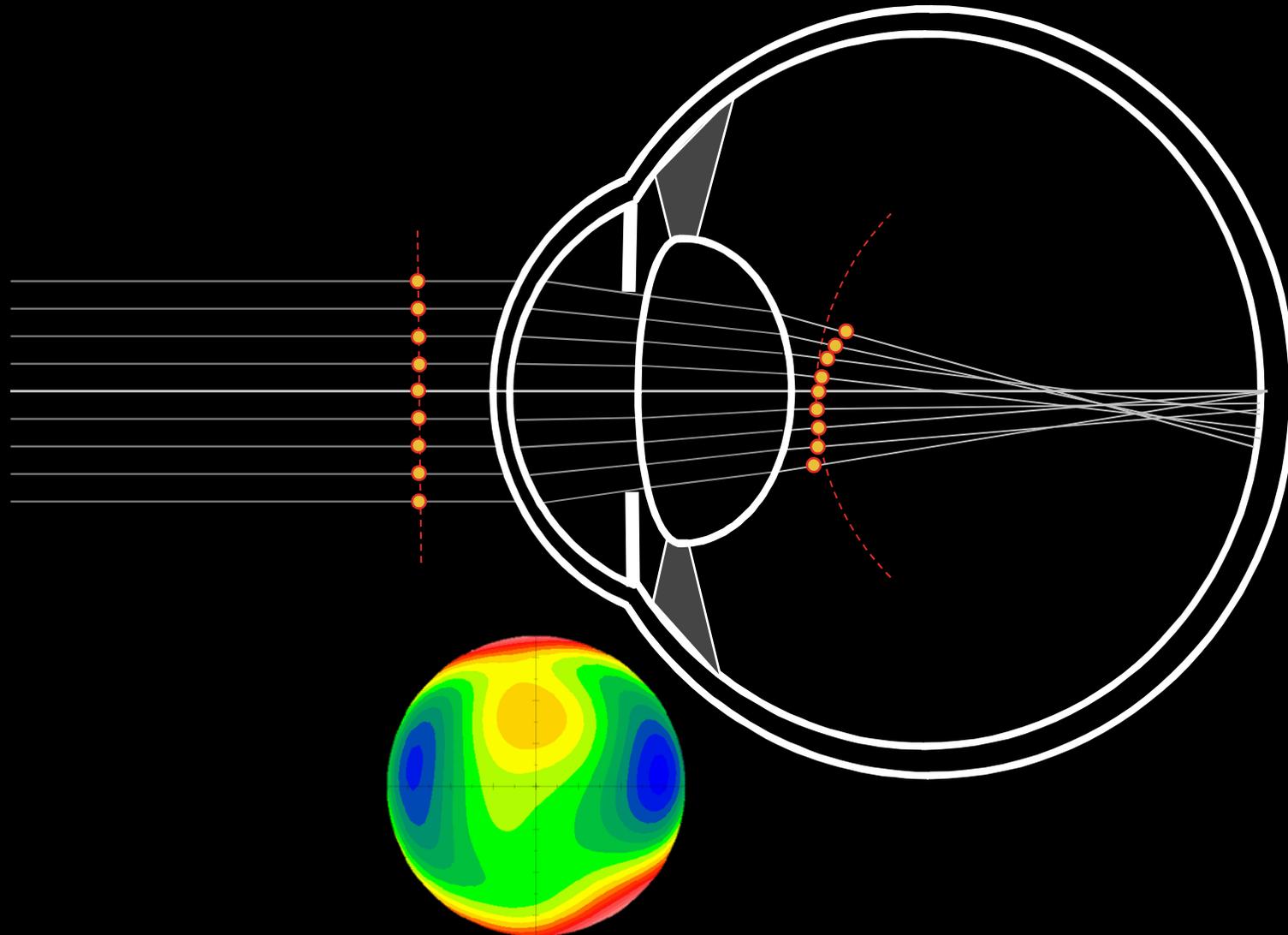
“A *wavefront* is the locus of points having the same phase”



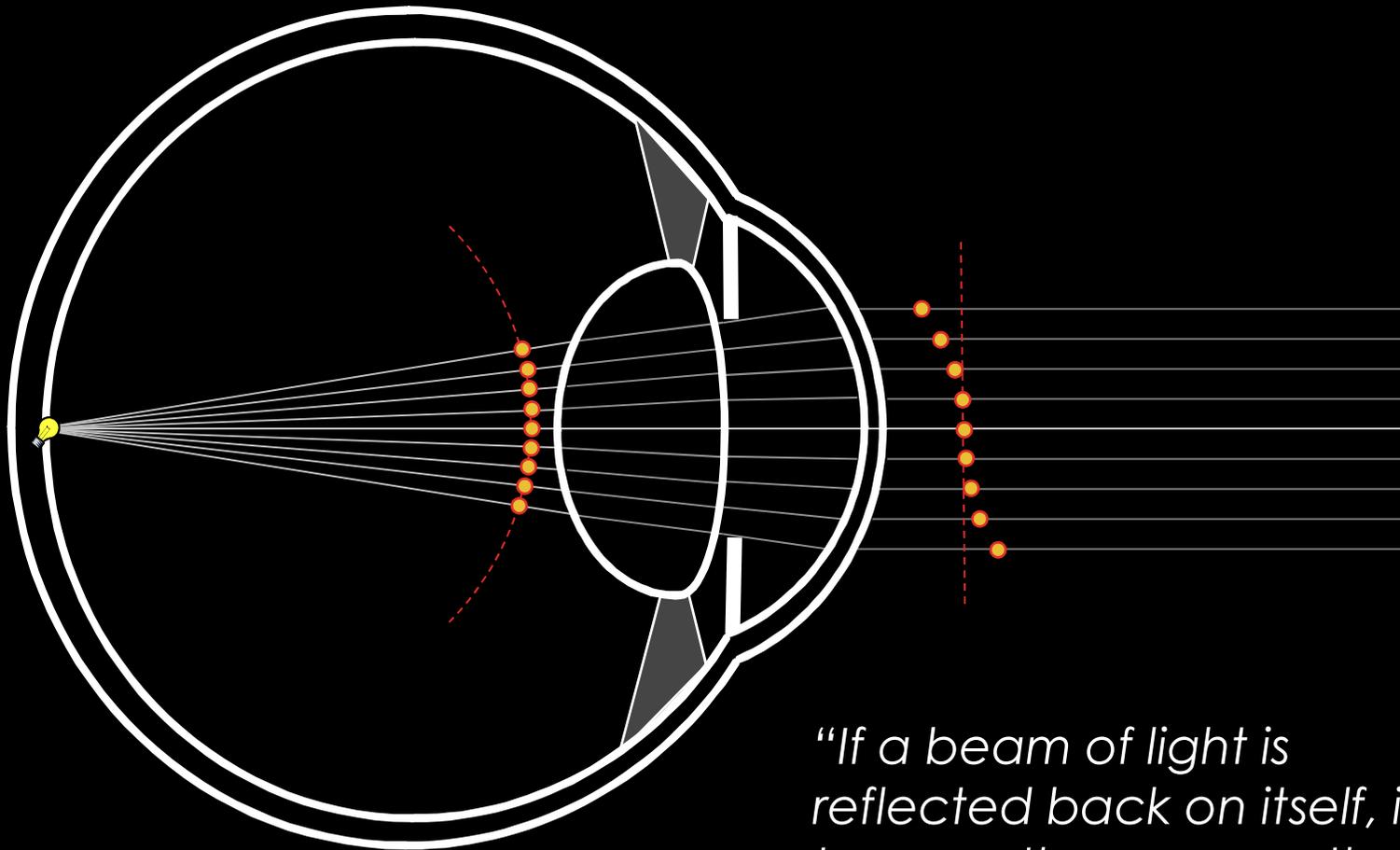
# WHAT IS THE WAVEFRONT?



## OPTICAL PATH DIFFERENCE - OPD



## WAVEFRONT ERROR - WFE



*“If a beam of light is reflected back on itself, it will traverse the same path as it did before reversal”*

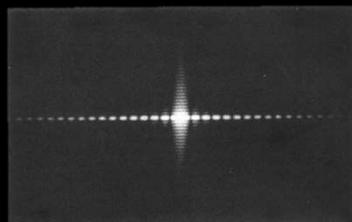
*“Any deviation of light rays from a rectilinear path which cannot be interpreted as reflection or refraction”*

*Sommerfeld, ~ 1894*

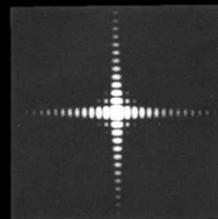
## DIFFRACTION AND INTERFERENCE

- diffraction causes light to bend perpendicular to the direction of the diffracting edge
- interference due to the size of the aperture causes the diffracted light to have peaks and valleys

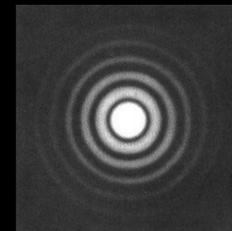
rectangular  
aperture



square  
aperture



circular  
aperture



PSF

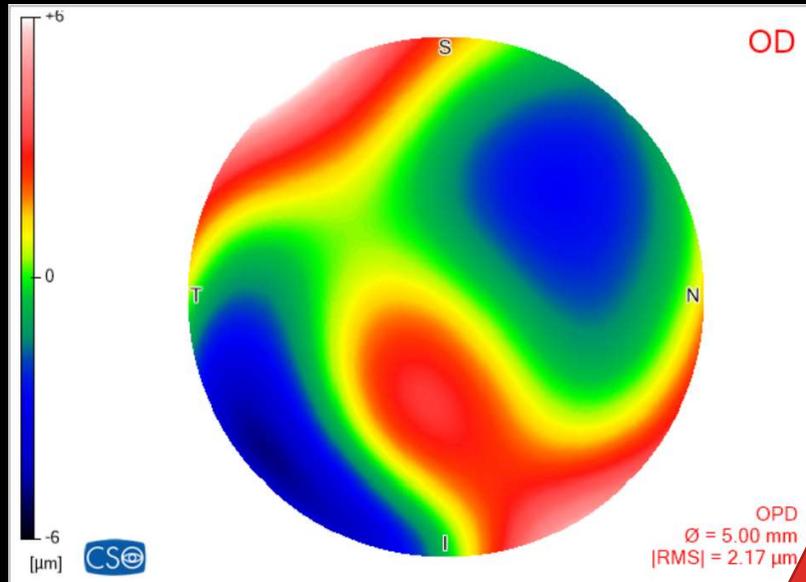
## POINT SPREAD FUNCTION (PSF)

The **Point Spread Function**, or **PSF**, is the image that an optical system forms of a point source.

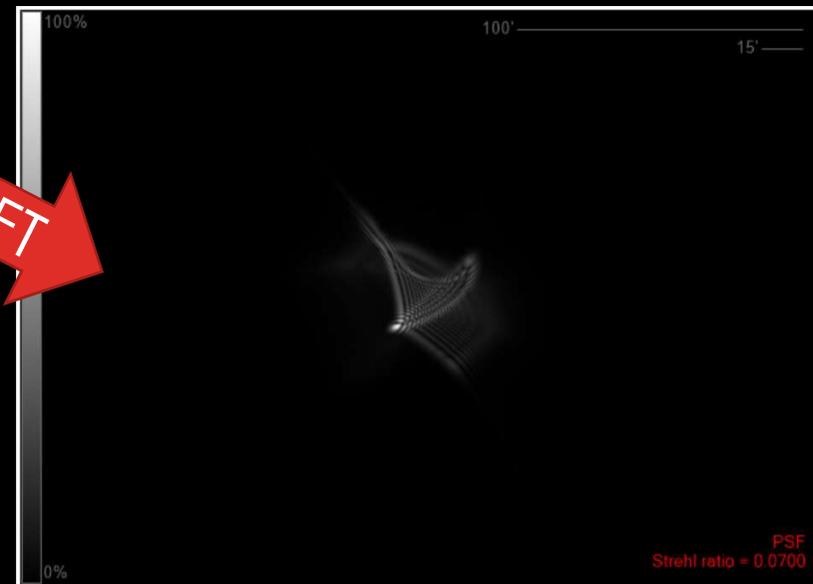
The point source is the most fundamental object, and forms the basis for any complex object.

*The PSF is analogous to the Impulse Response Function in electronics.*

# POINT SPREAD FUNCTION (PSF)



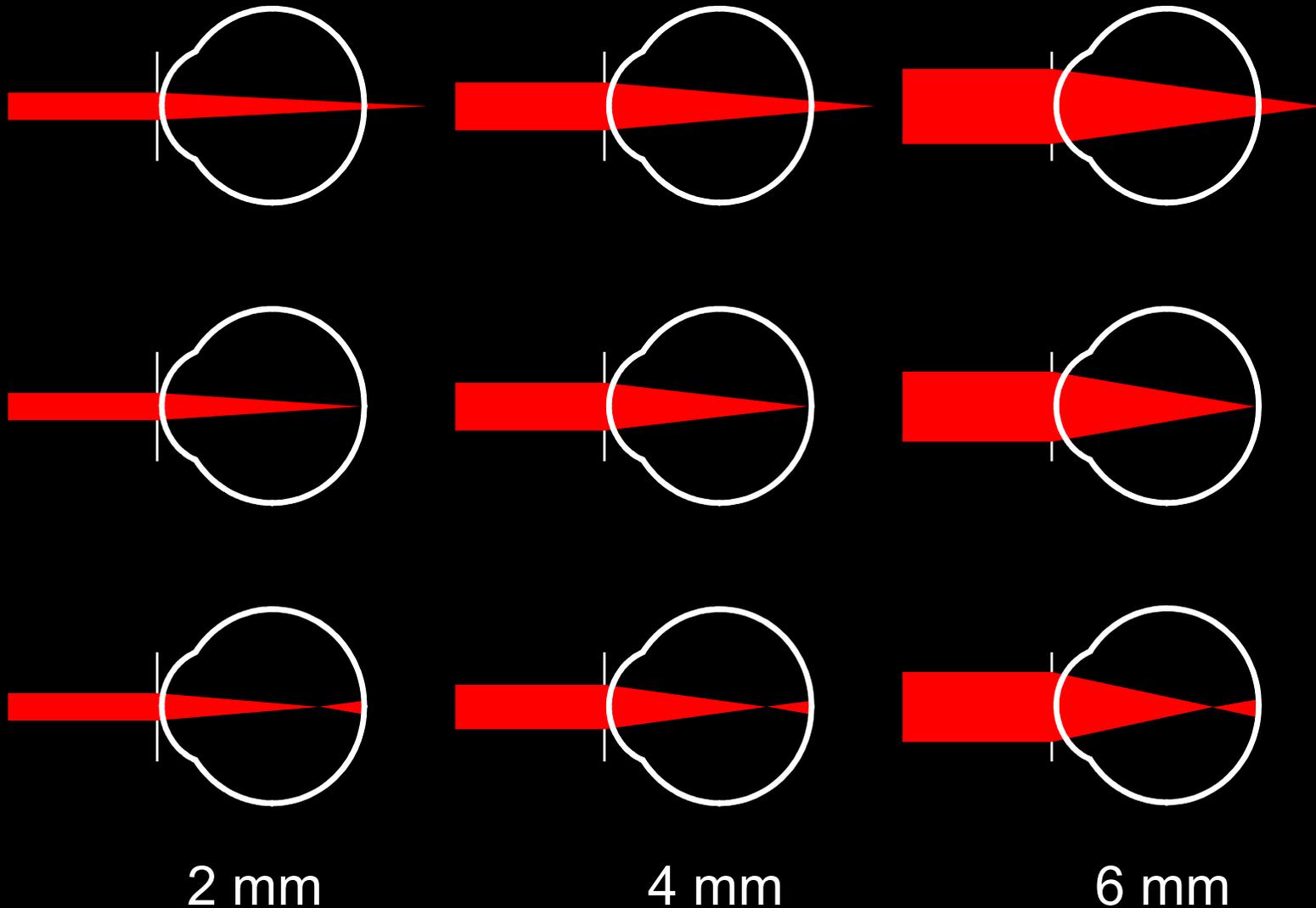
FFT

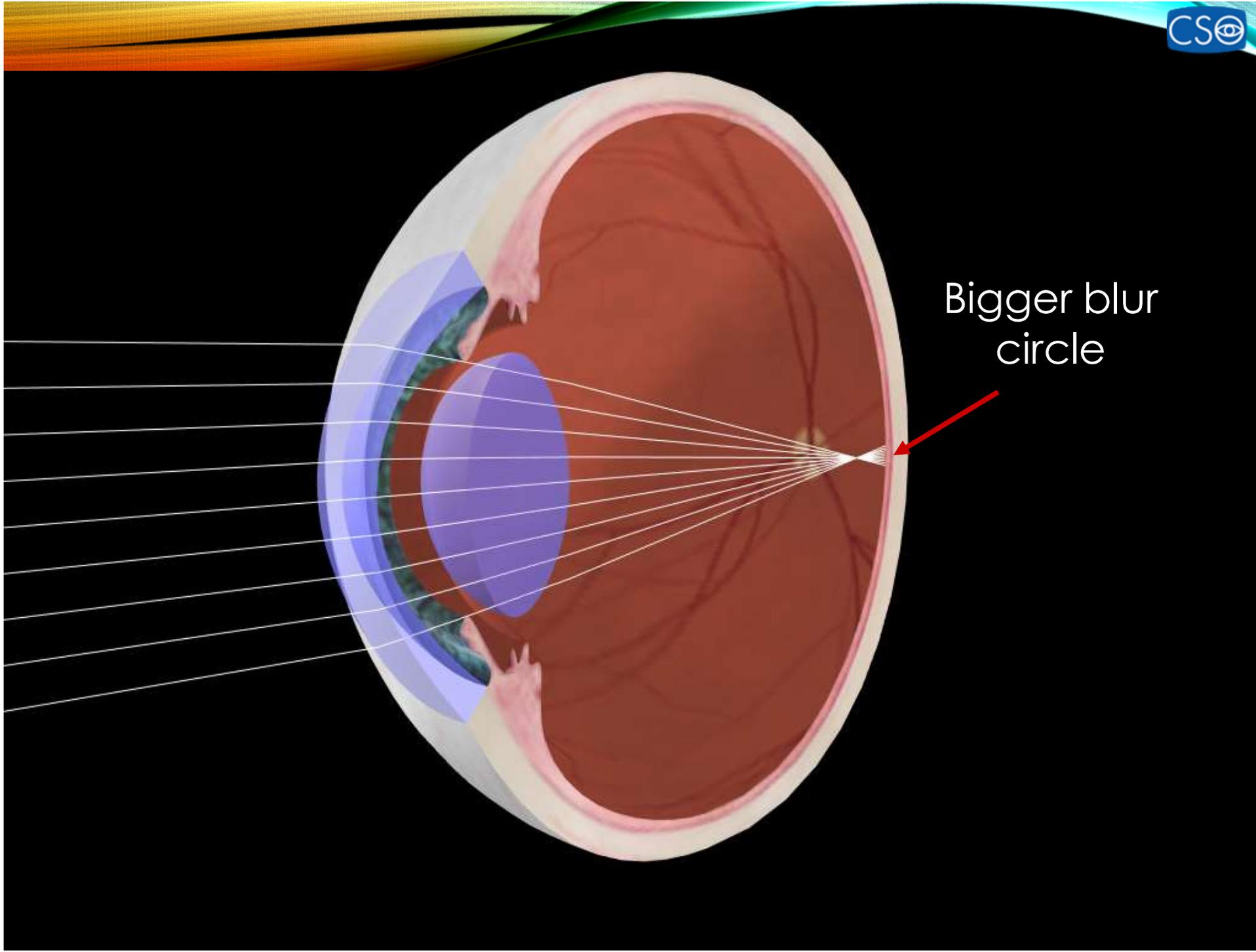


DEMONSTRATION:  
*OBSERVE YOUR OWN POINT SPREAD FUNCTION*

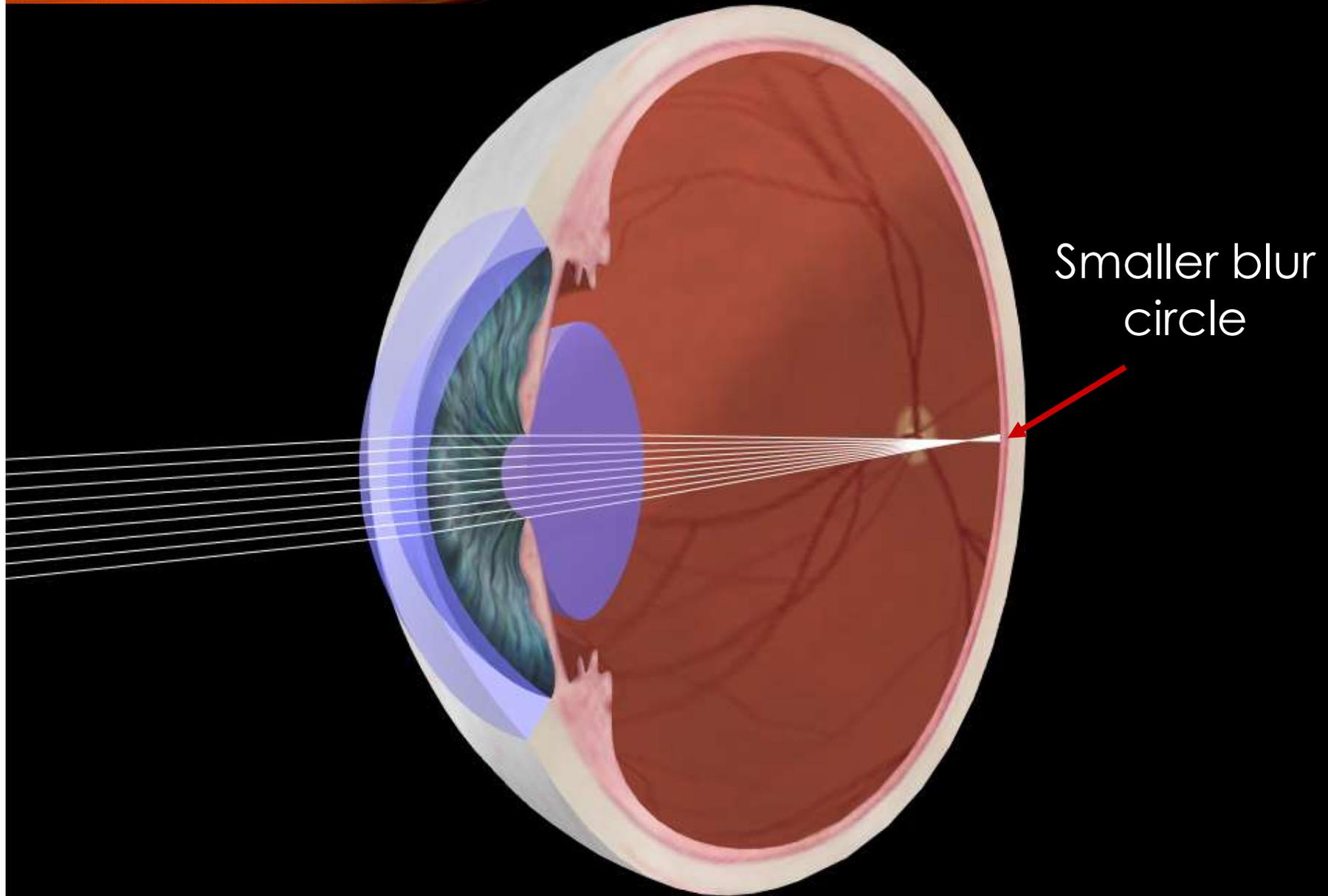


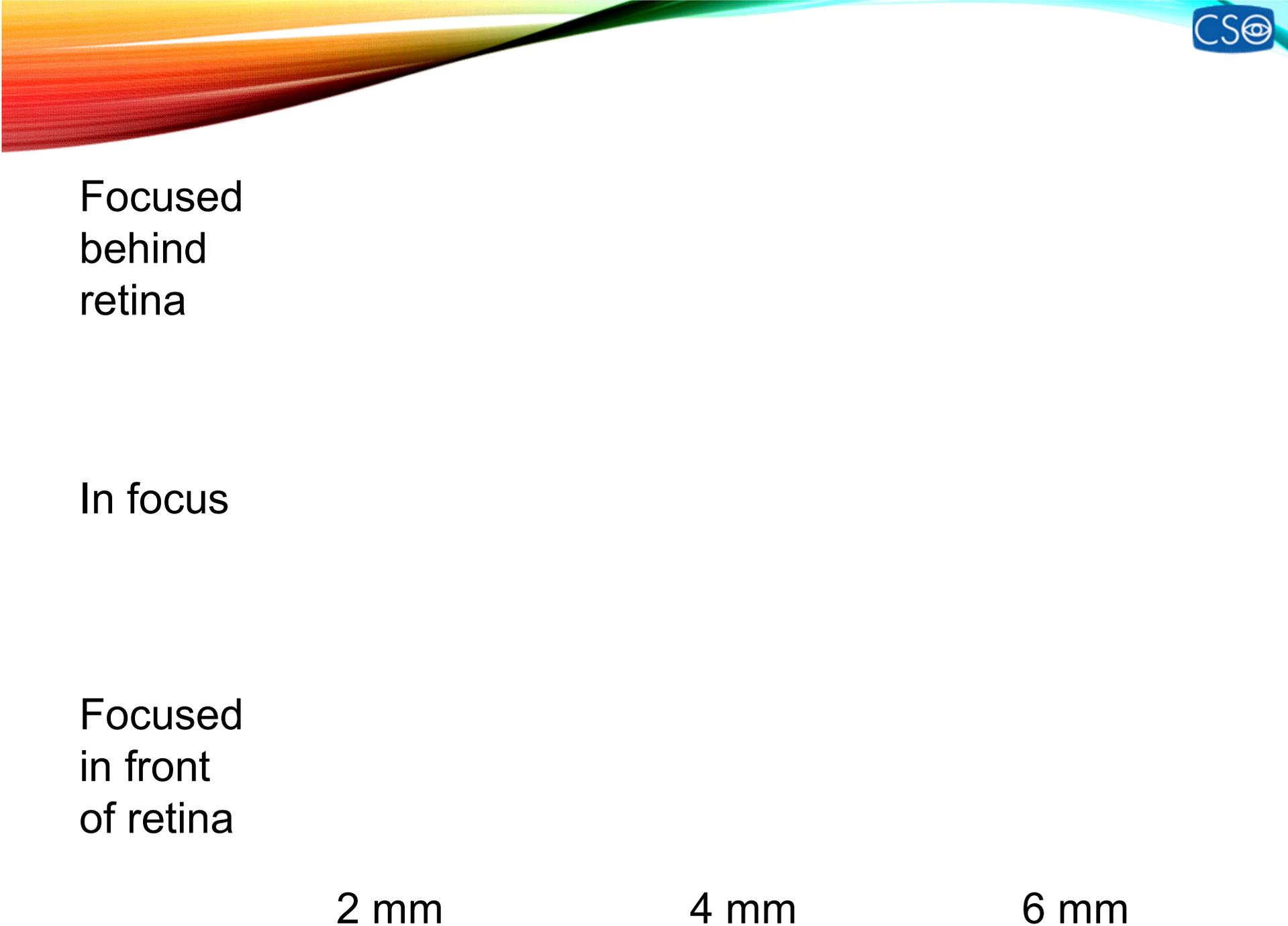
# DEPTH OF FOCUS: RELATIONSHIPS BETWEEN PUPIL SIZE, REFRACTIVE ERROR AND BLUR





Bigger blur circle





Focused  
behind  
retina

In focus

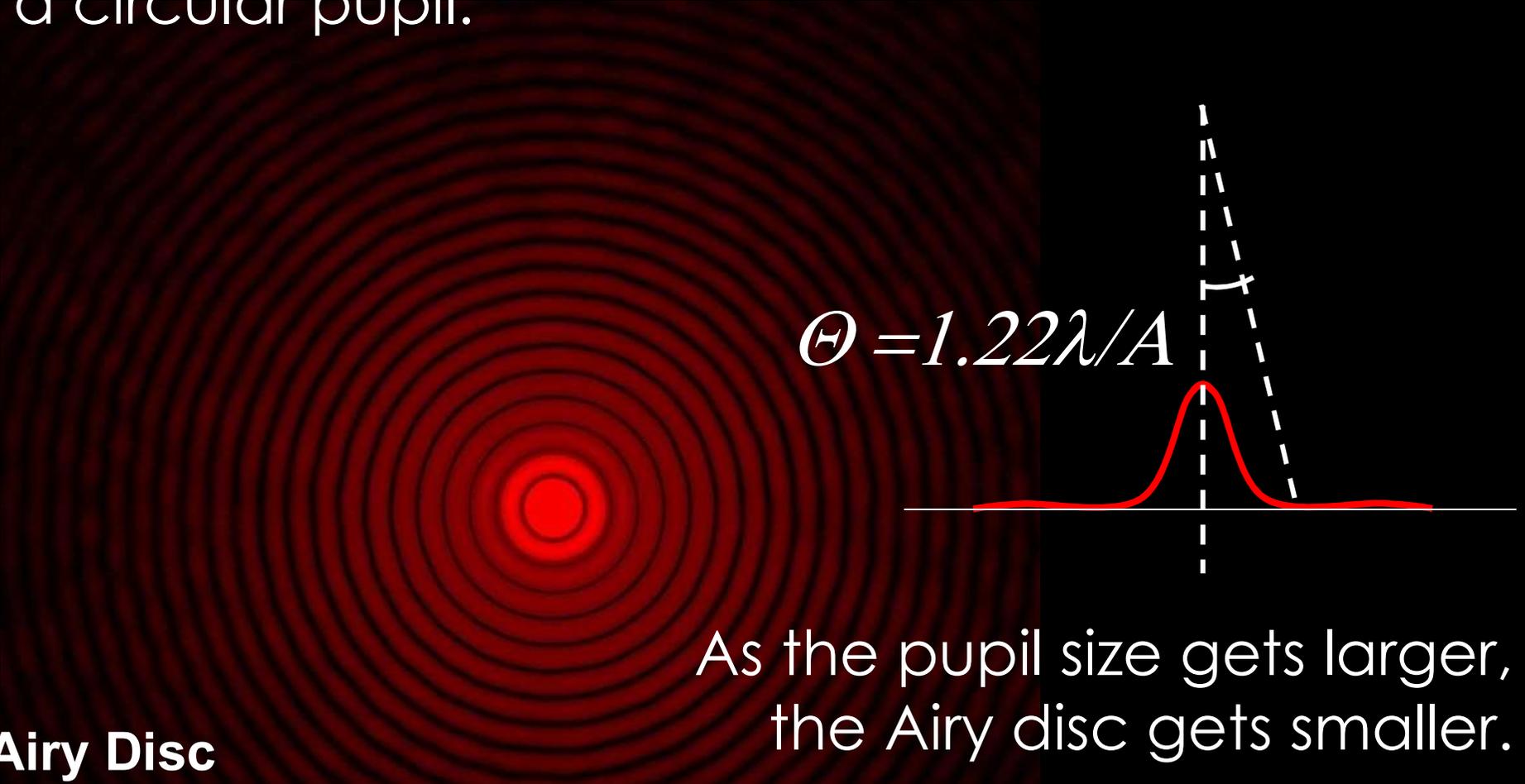
Focused  
in front  
of retina

2 mm

4 mm

6 mm

The PSF for a perfect optical system is the Airy disc, which is the Fraunhofer diffraction pattern for a circular pupil.



The image shows a 2D diffraction pattern of concentric red rings on the left, representing the Airy disc. On the right, a 1D intensity profile is shown as a red curve with a central peak and smaller side lobes. A vertical dashed line marks the center, and a horizontal dashed line indicates the radius of the first minimum. The equation  $\Theta = 1.22\lambda/A$  is placed near the first minimum.

$$\Theta = 1.22\lambda/A$$

As the pupil size gets larger,  
the Airy disc gets smaller.

# POINT SPREAD FUNCTION VS. PUPIL SIZE PERFECT EYE

1 mm



2 mm



3 mm



4 mm



5 mm



6 mm



7 mm

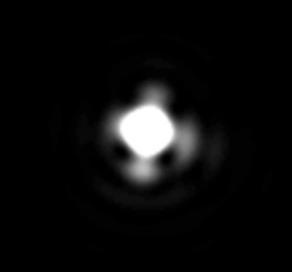


# POINT SPREAD FUNCTION VS. PUPIL SIZE TYPICAL EYE

1 mm



2 mm



3 mm



4 mm



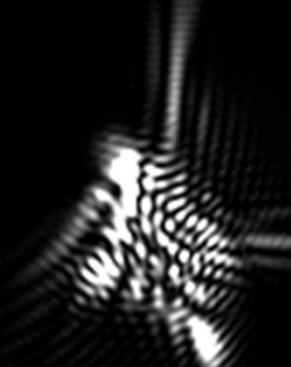
5 mm



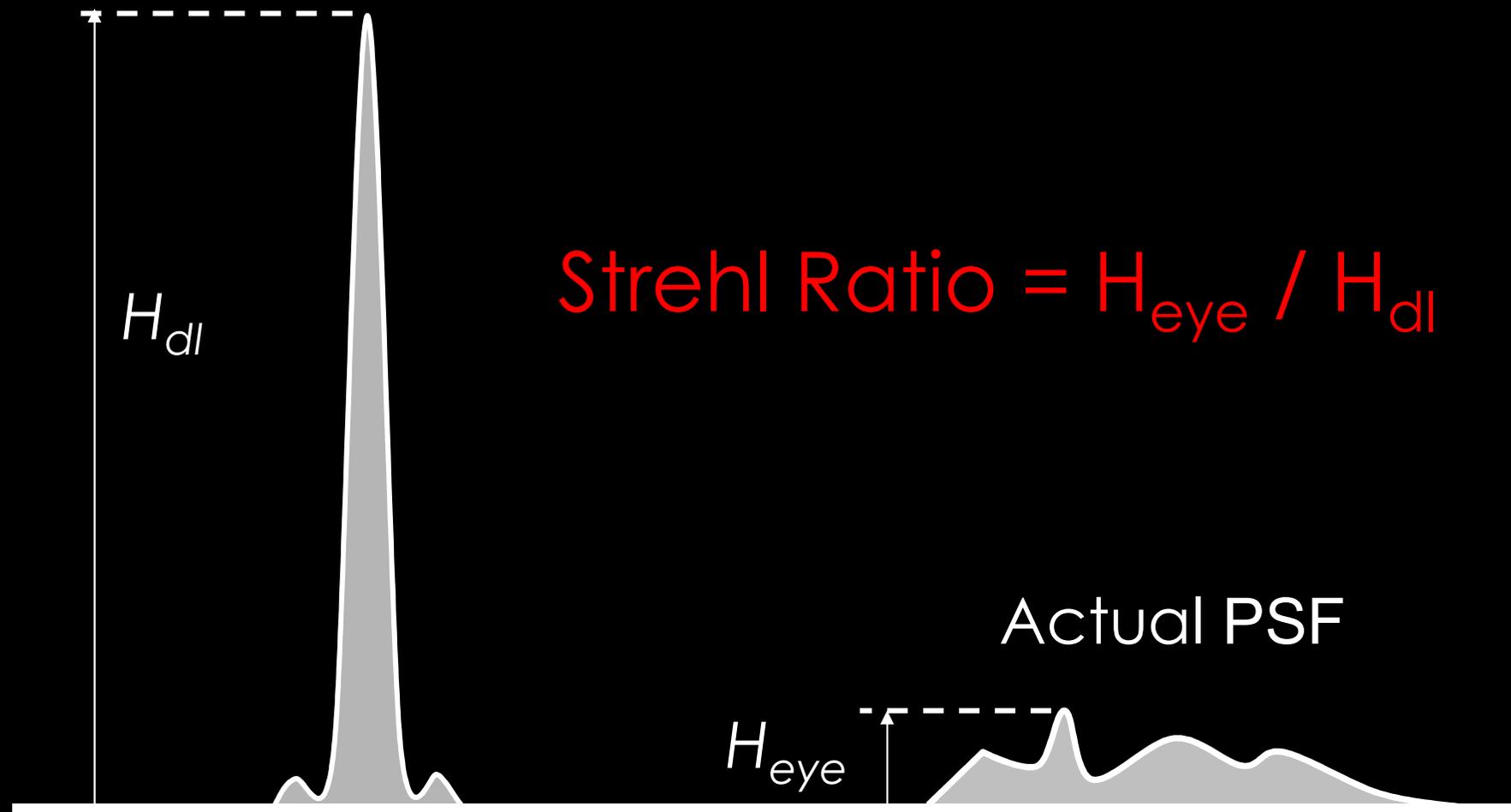
6 mm



7 mm



## Diffraction-Limited PSF

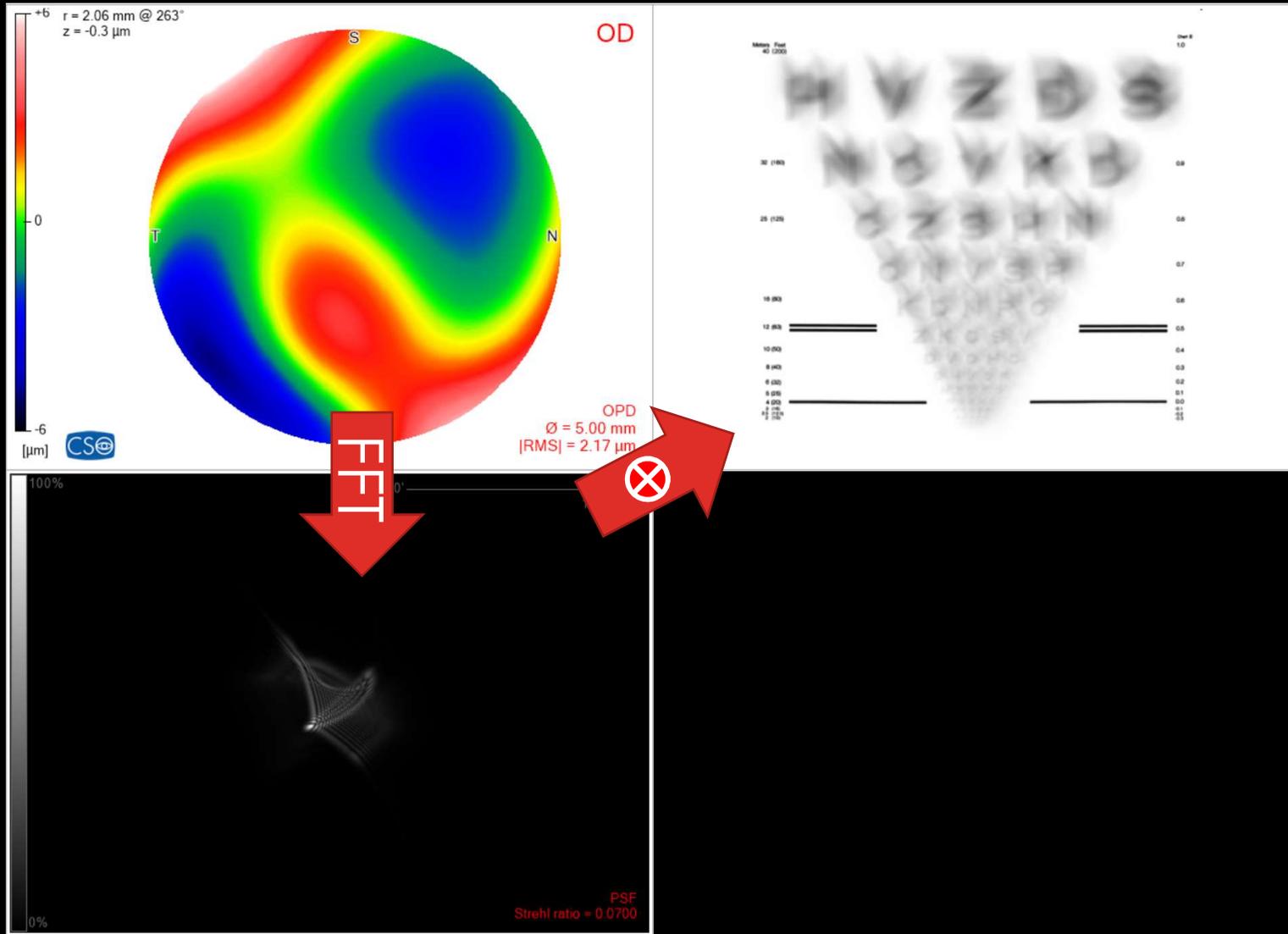


## CONVOLUTION



The diagram illustrates the convolution process. On the left, a point spread function (PSF) kernel is shown as a central white point with three faint, radiating lines. This kernel is convolved with an input image, represented by a white 'E' character. The convolution operation is indicated by a circle with an 'X' inside. The result is an output image, also a white 'E' character, but significantly blurred and spread out, demonstrating the effect of convolution on image resolution.

# CONVOLUTION: SIMULATED IMAGES

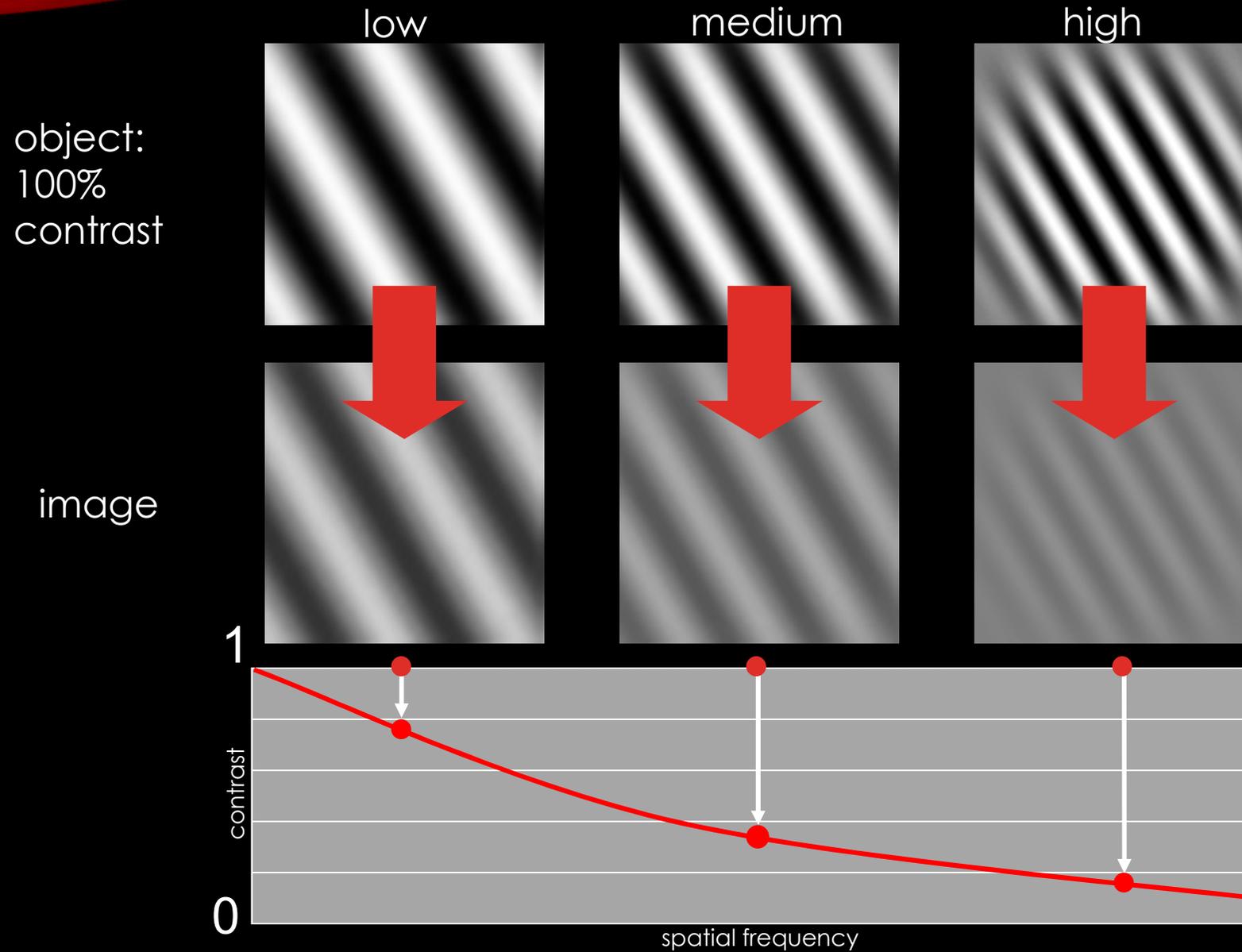


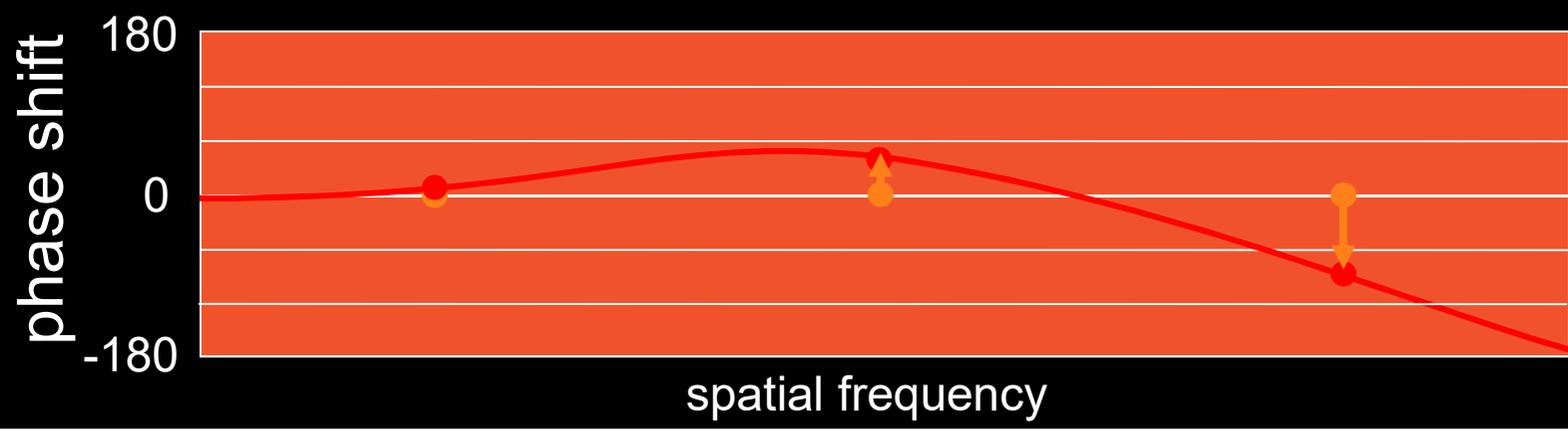
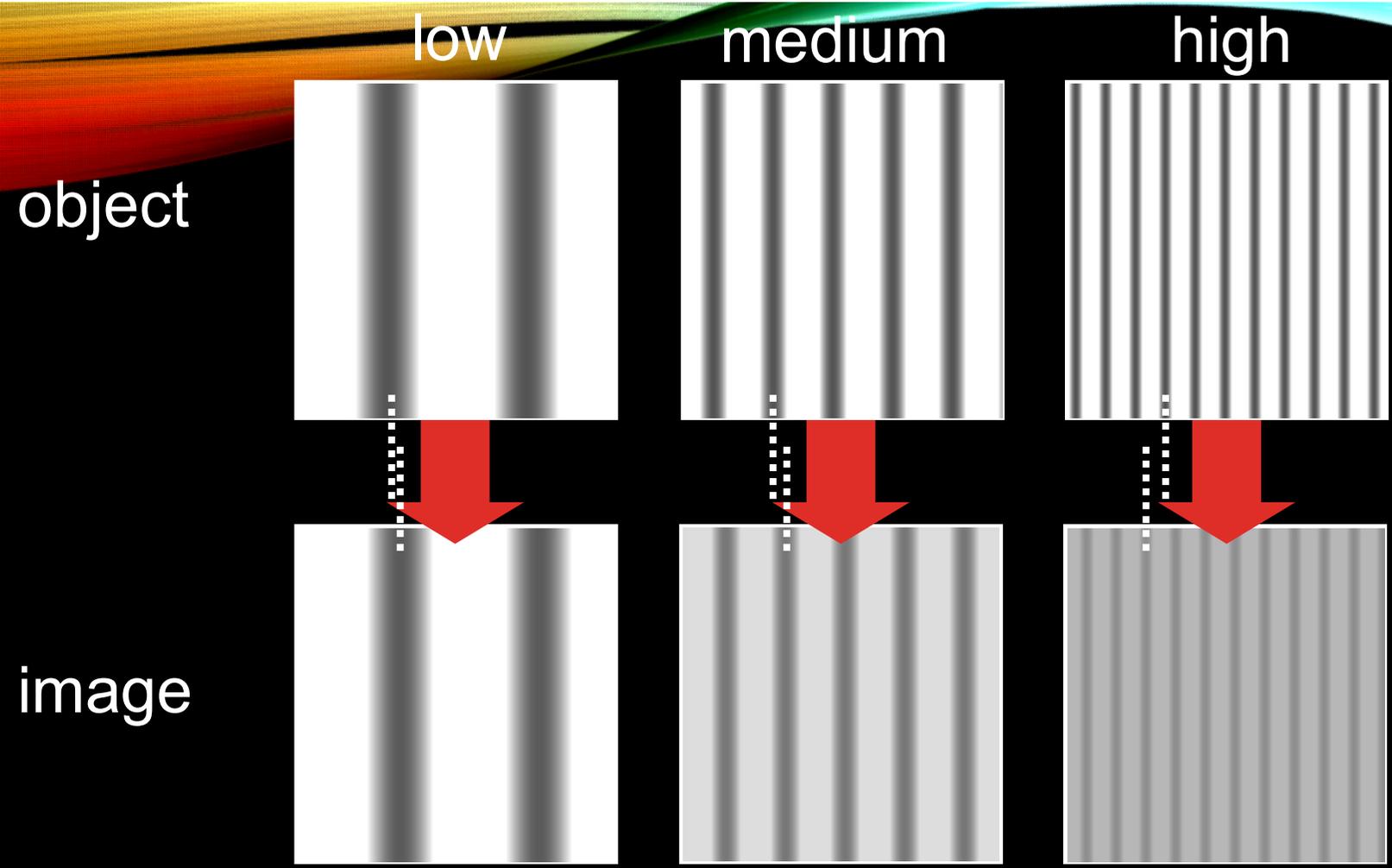
MTF

# MODULATION TRANSFER FUNCTION (MTF)

- The **Modulation Transfer Function (MTF)** indicates the ability of an optical system to reproduce (transfer) various levels of detail (spatial frequencies) from the object to the image.
- Its units are the ratio of image contrast over the object contrast as a function of spatial frequency.
- It is the optical contribution to the contrast sensitivity function (CSF).

# MODULATION TRANSFER FUNCTION (MTF)





$$PSF(x_i, y_i) = FT \left\{ P(x, y) e^{-i \frac{2\pi}{\lambda} W(x, y)} \right\}$$

$$MTF(f_x, f_y) = \text{Amplitude} \left[ FT \{ PSF(x_i, y_i) \} \right]$$

$$PTF(f_x, f_y) = \text{Phase} \left[ FT \{ PSF(x_i, y_i) \} \right]$$

# ABERROMETERS

## OCULAR ABERROMETER

