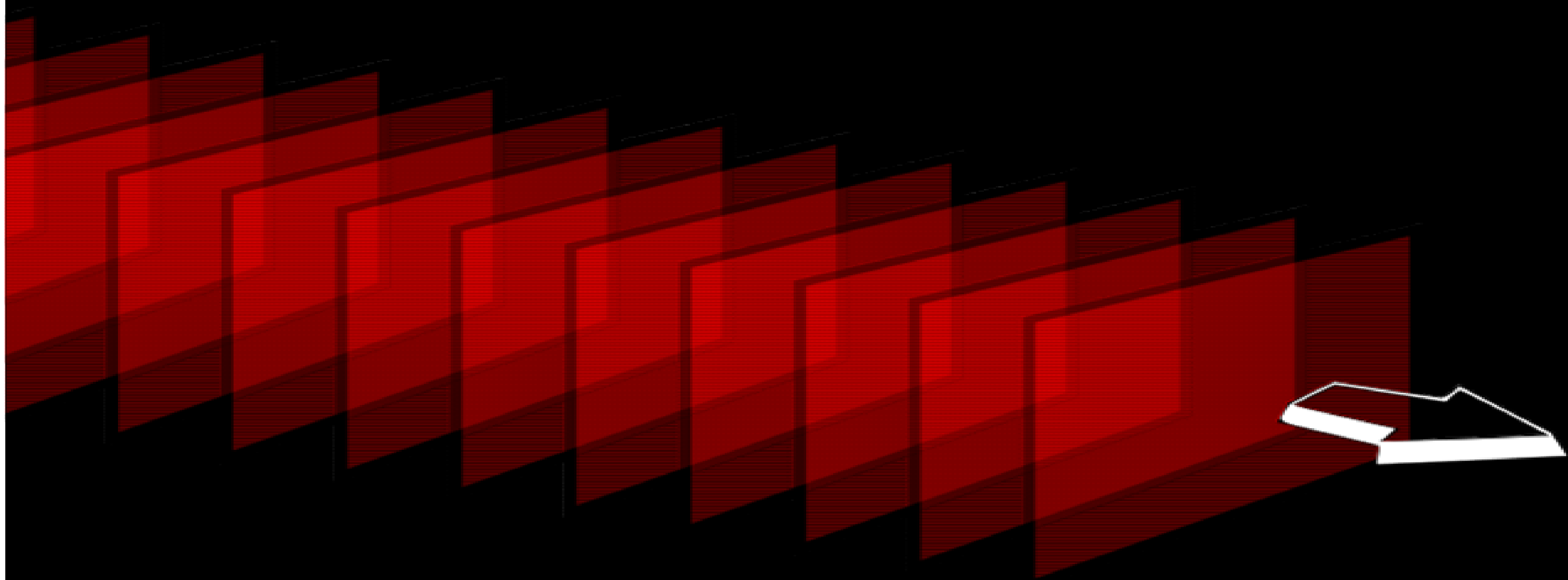
A REVIEW OF ABERROMETRY

Francesco Versaci

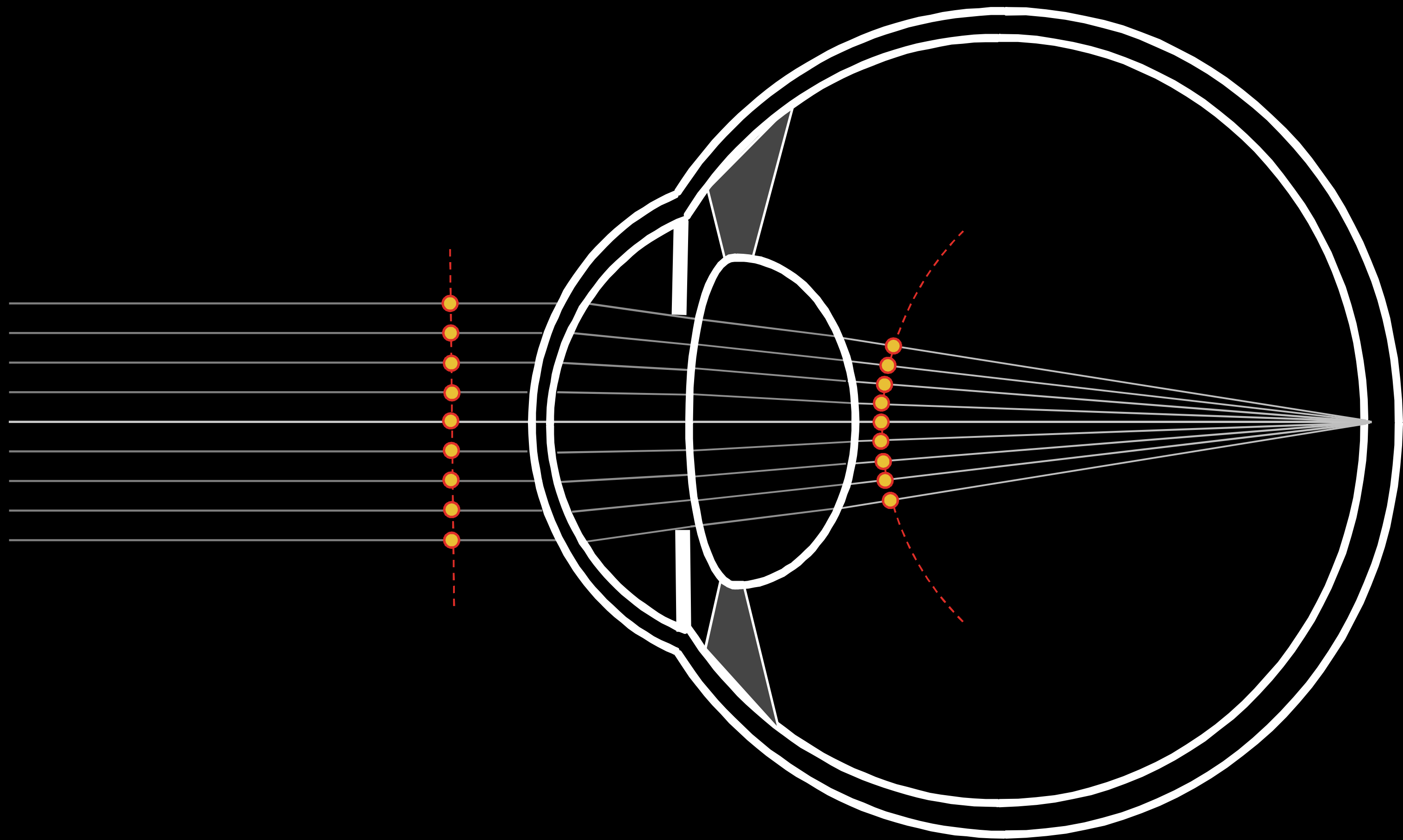
WAVEFRONT

WHAT IS THE WAVEFRONT?

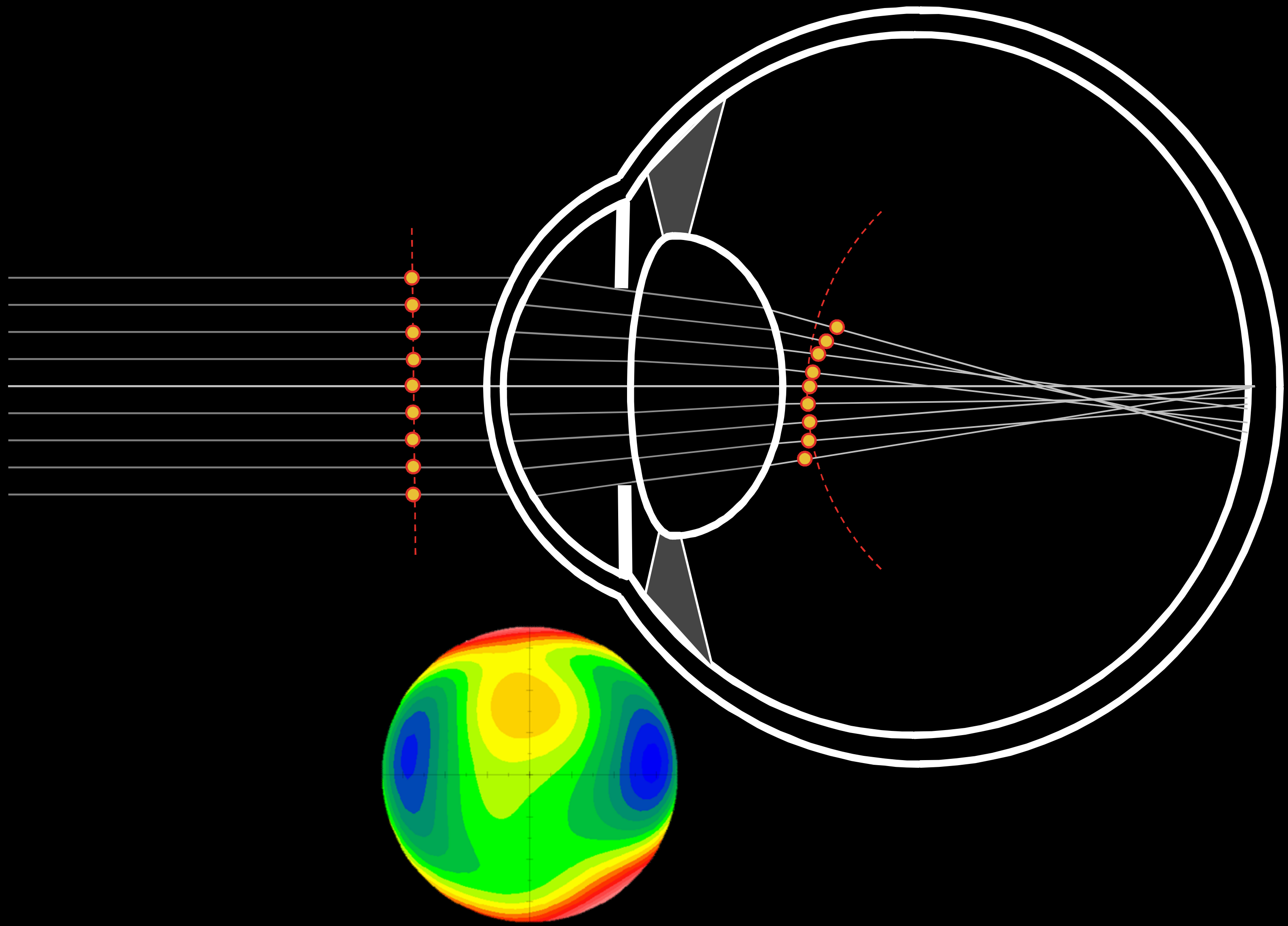
"A wavefront is the locus of points having the same phase"



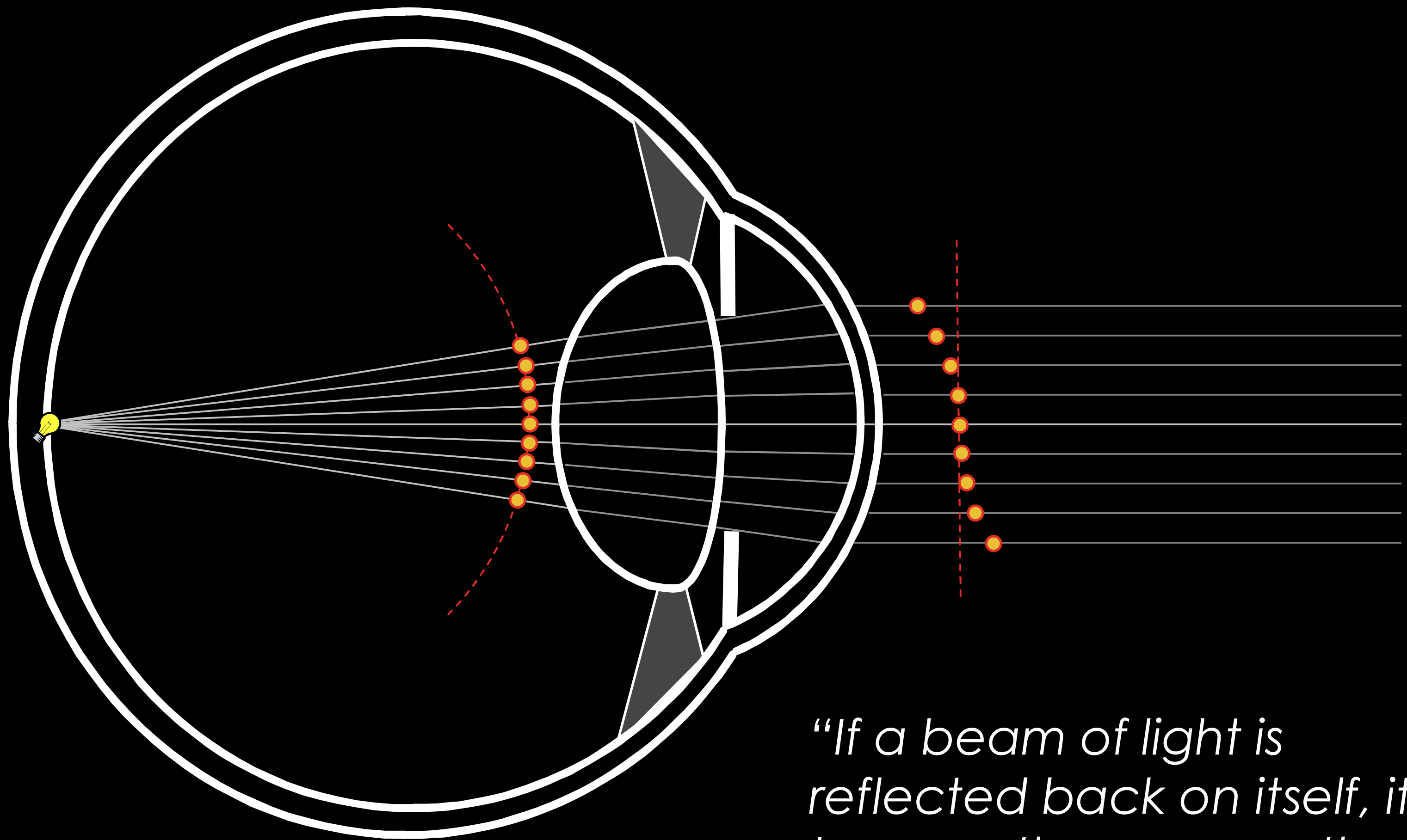
WHAT IS THE WAVEFRONT?



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"

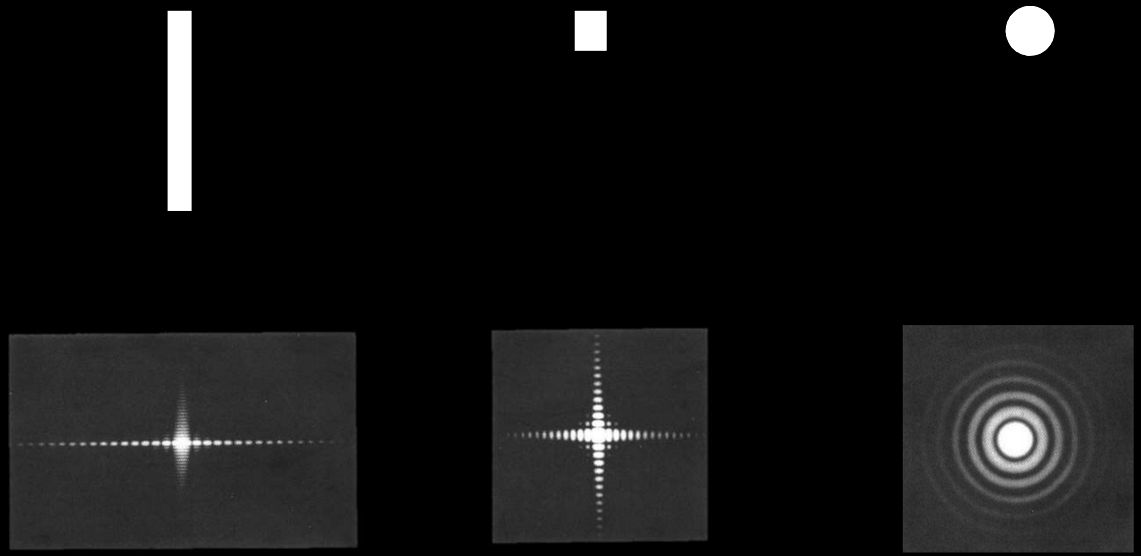
"Any deviation of light rays from a rectilinear path which cannot be interpreted as reflection or refraction"

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

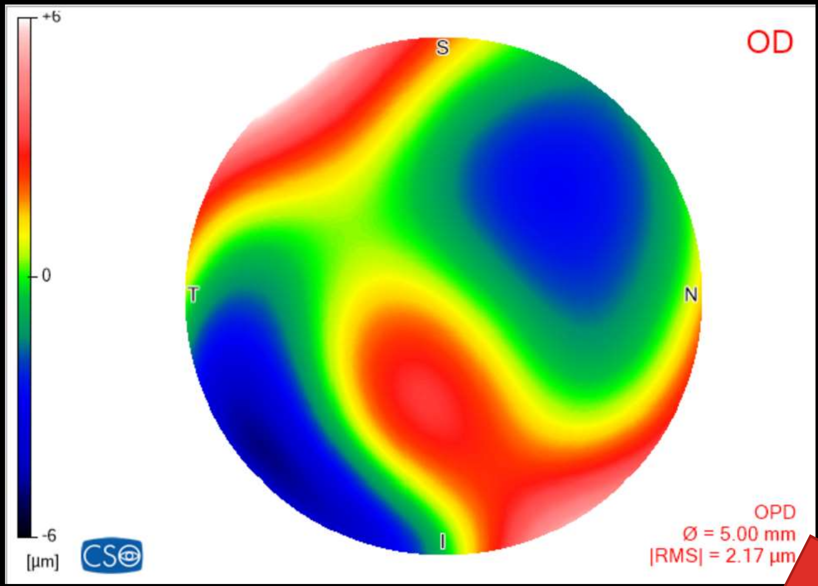
POINT SPREAD FUNCTION (PSF)

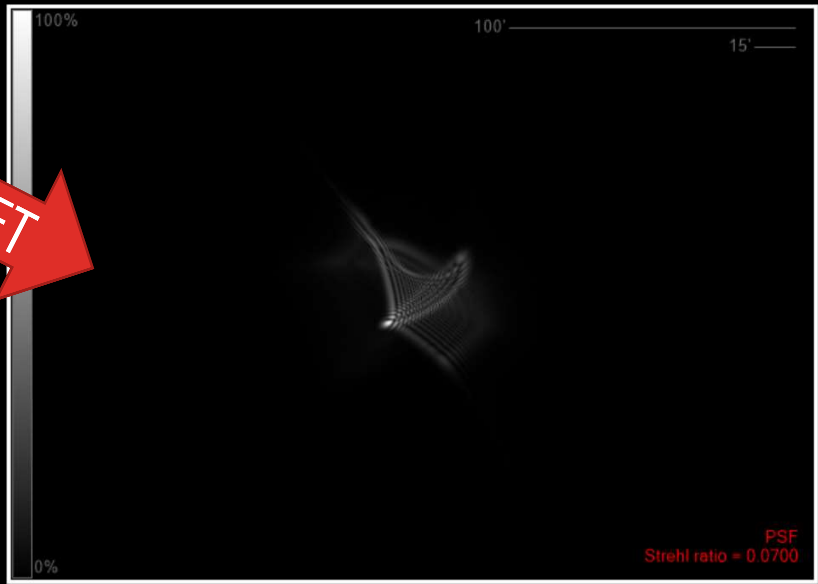
The Point Spread Function, or PSF, is the image that an optical system forms of a point source.

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.

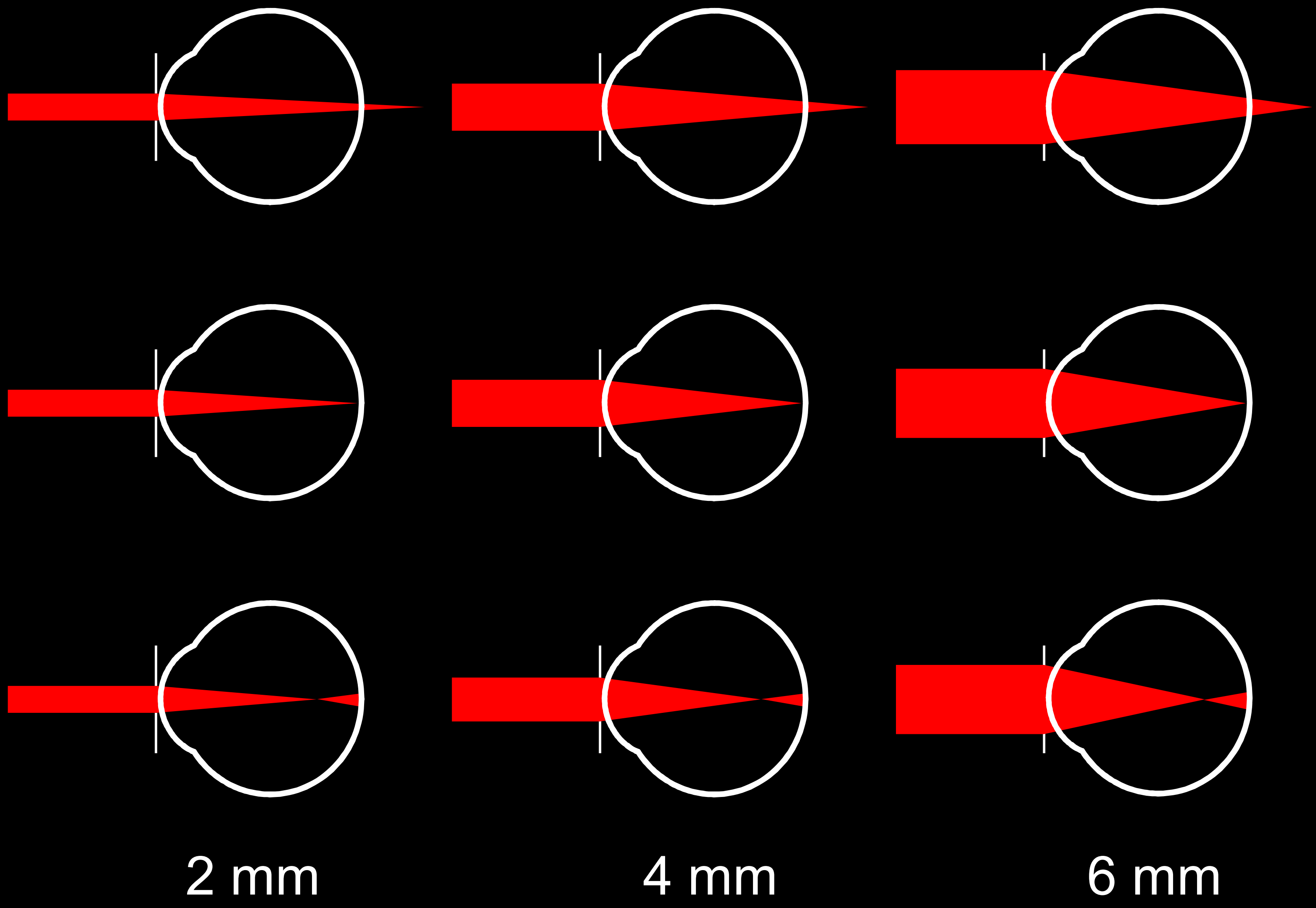
POINT SPREAD FUNCTION (PSF)

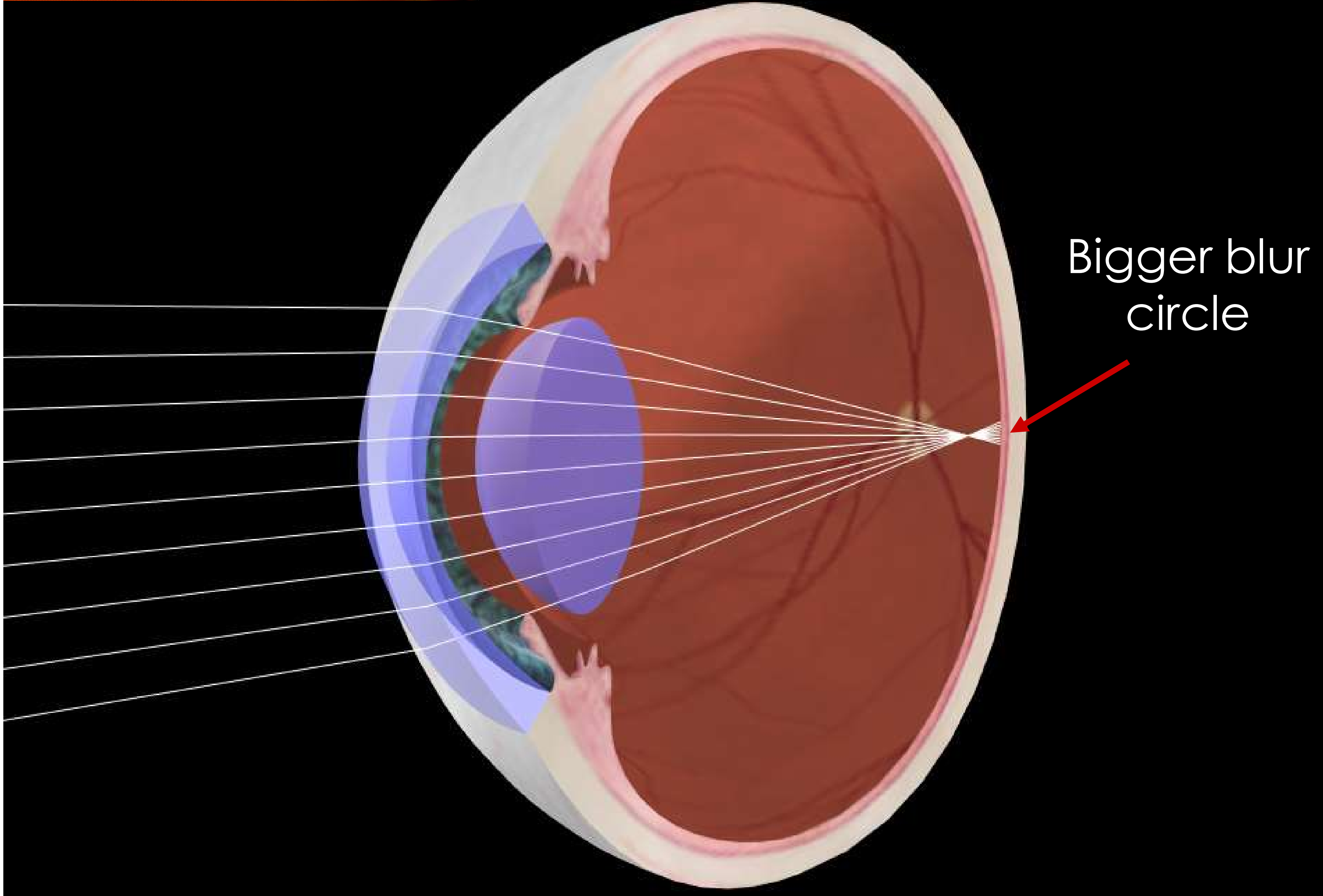


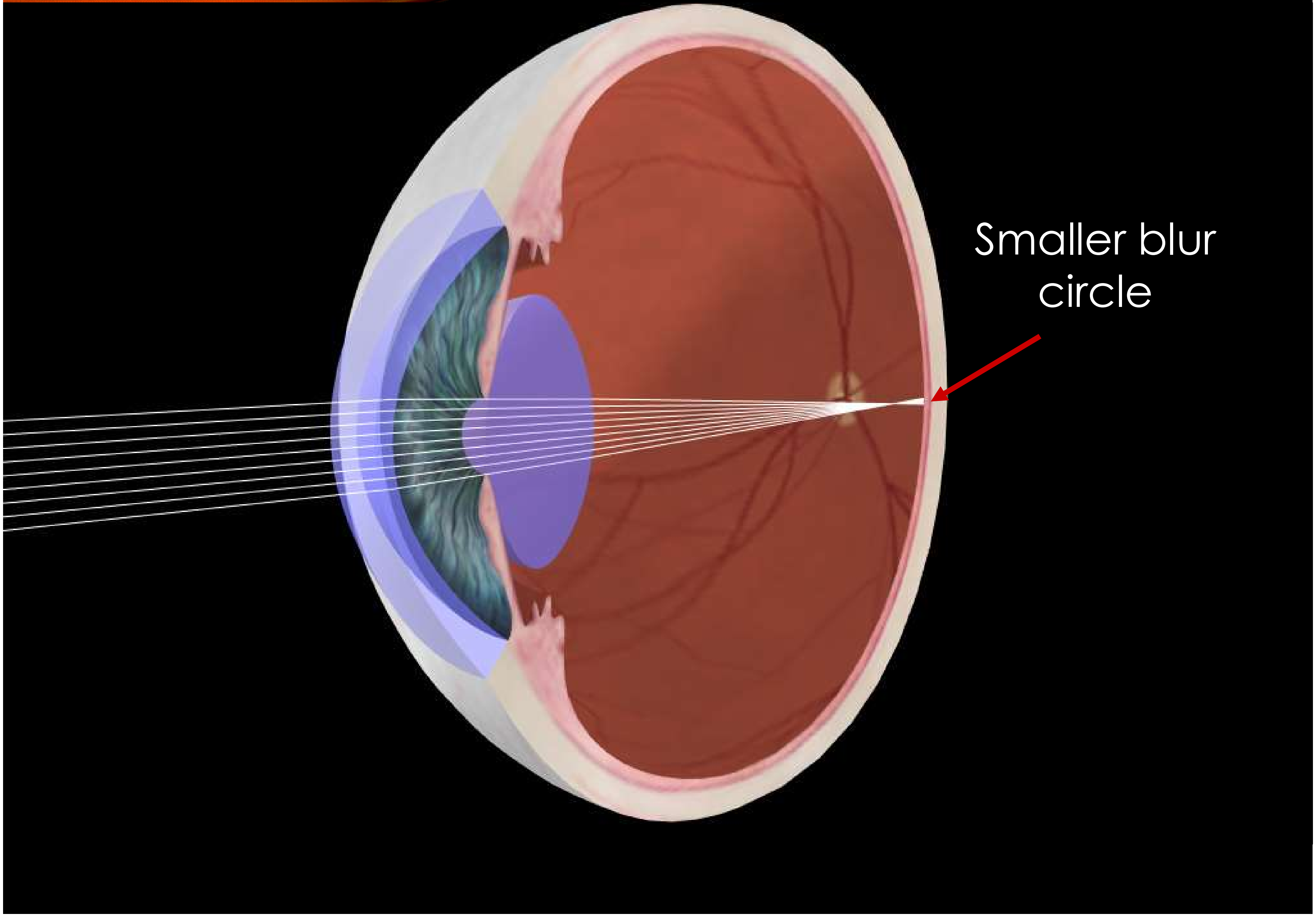


DEMONSTRATION:
OBSERVE YOUR OWN POINT SPREAD FUNCTION

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




Bigger blur
circle


Smaller blur circle

Focused behind retina

In focus

Focused in front of retina

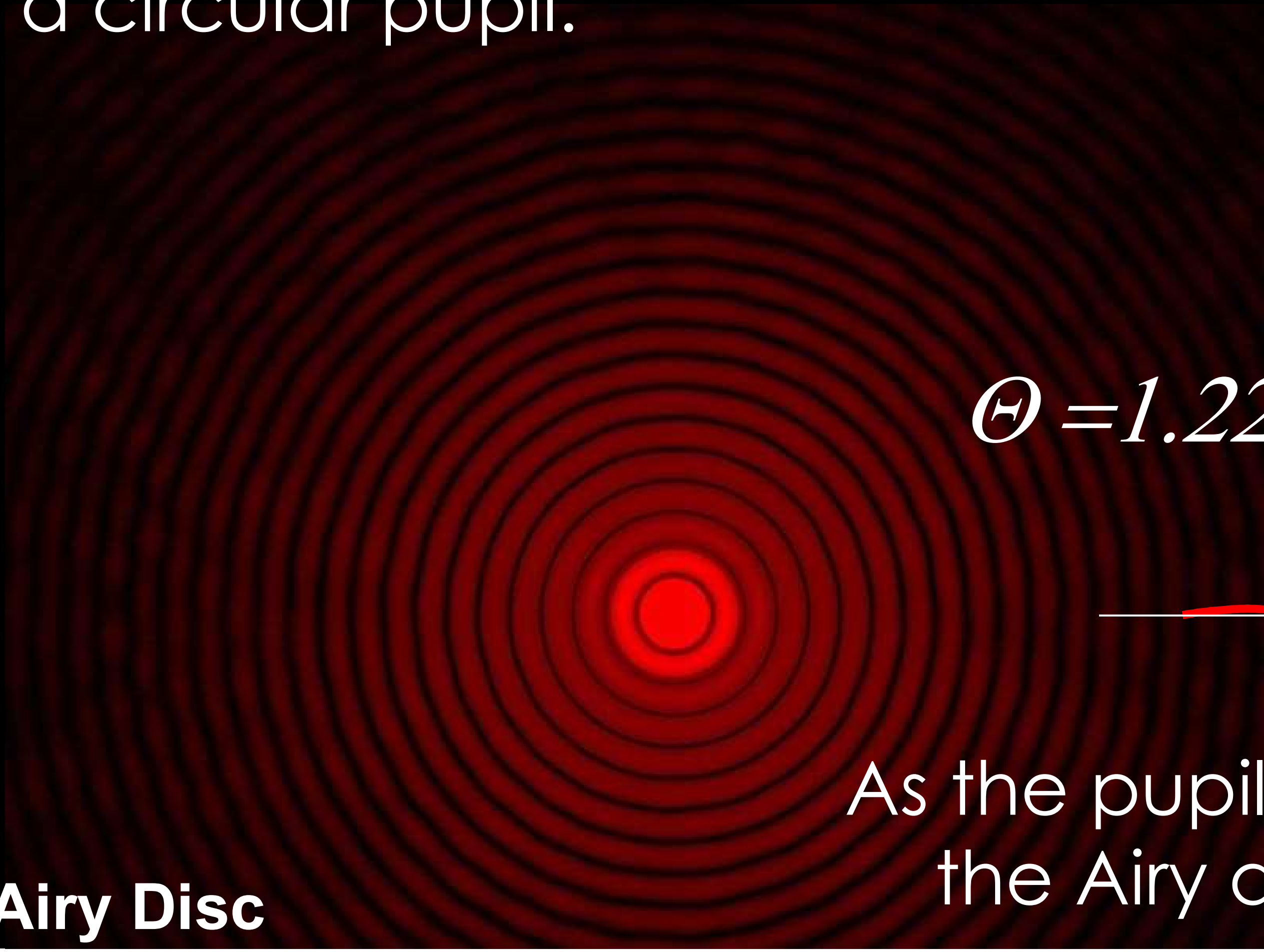
2 mm

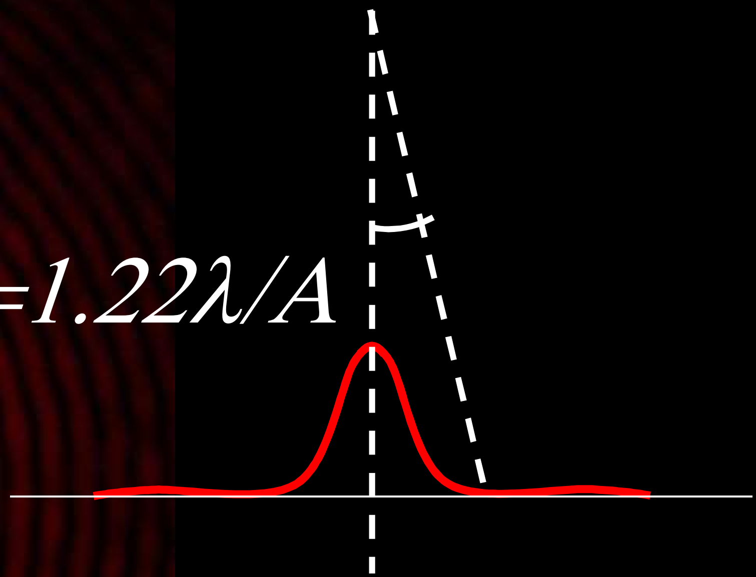
4 mm

6 mm

AIRY DISC

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

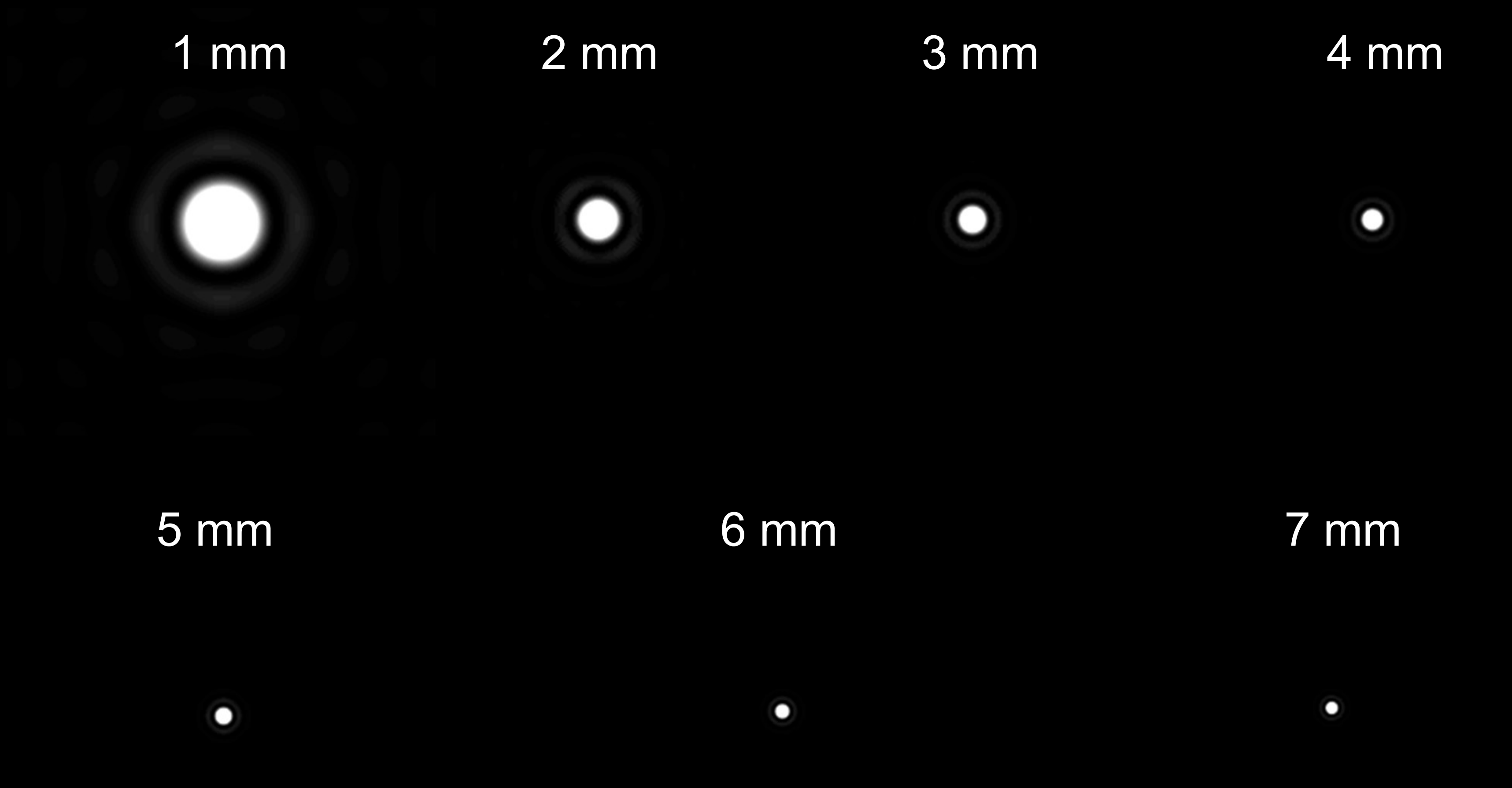




$$\Theta = 1.22\lambda/A$$

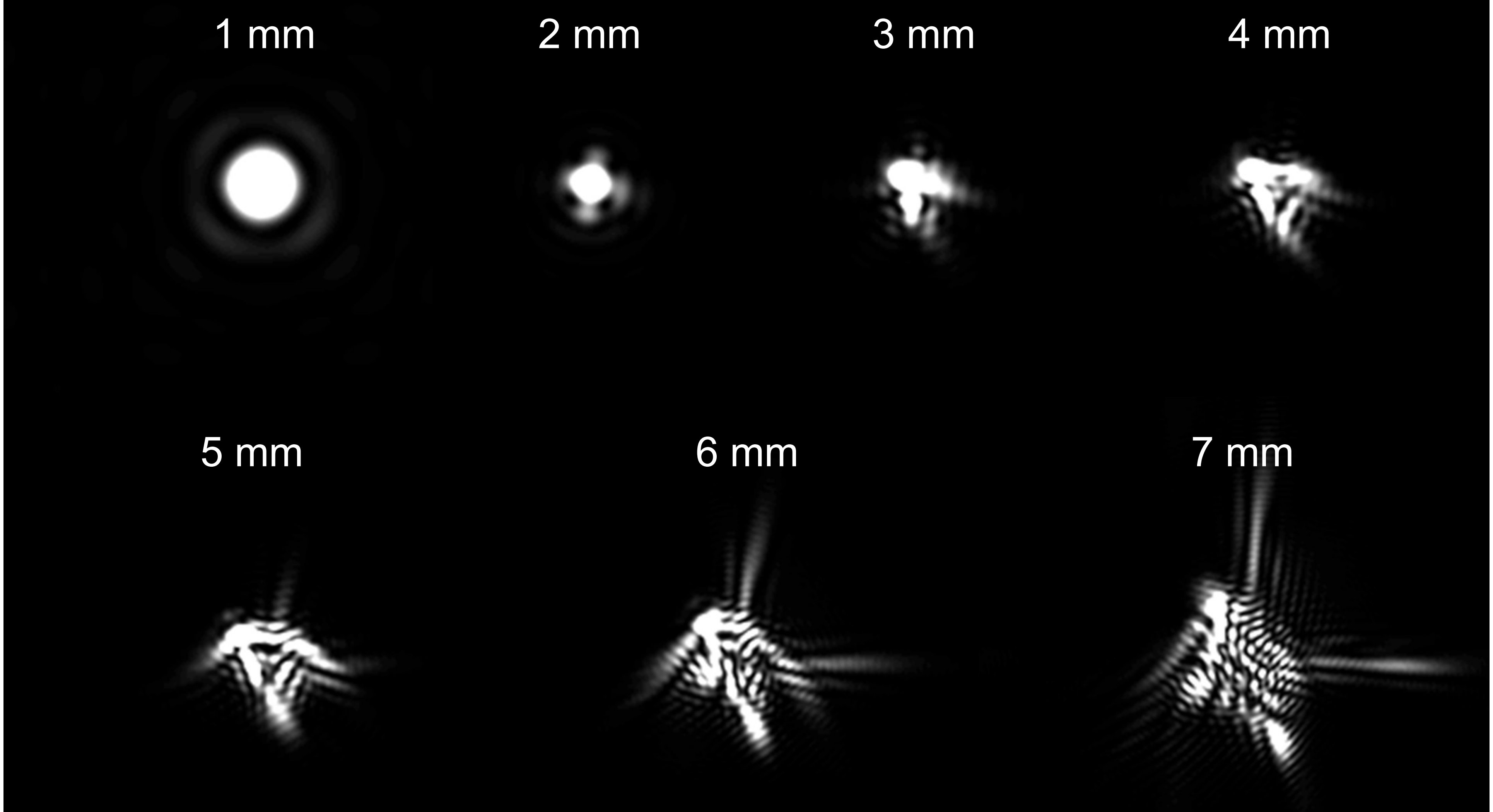
As the pupil size gets larger, the Airy disc gets smaller.

POINT SPREAD FUNCTION VS. PUPIL SIZE
PERFECT EYE



courtesy of Austin Roorda

POINT SPREAD FUNCTION VS. PUPIL SIZE
TYPICAL EYE

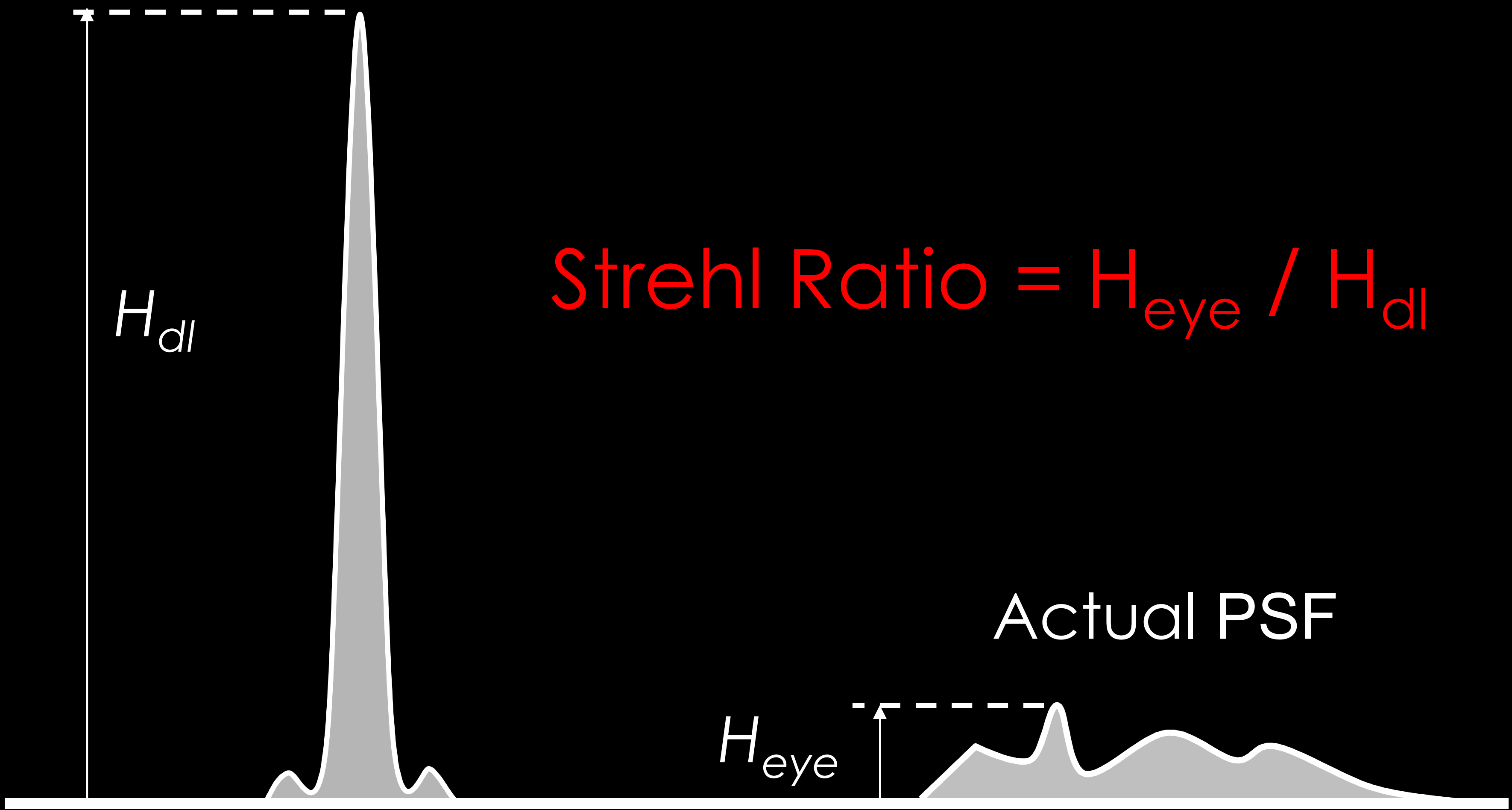


courtesy of Austin Roorda

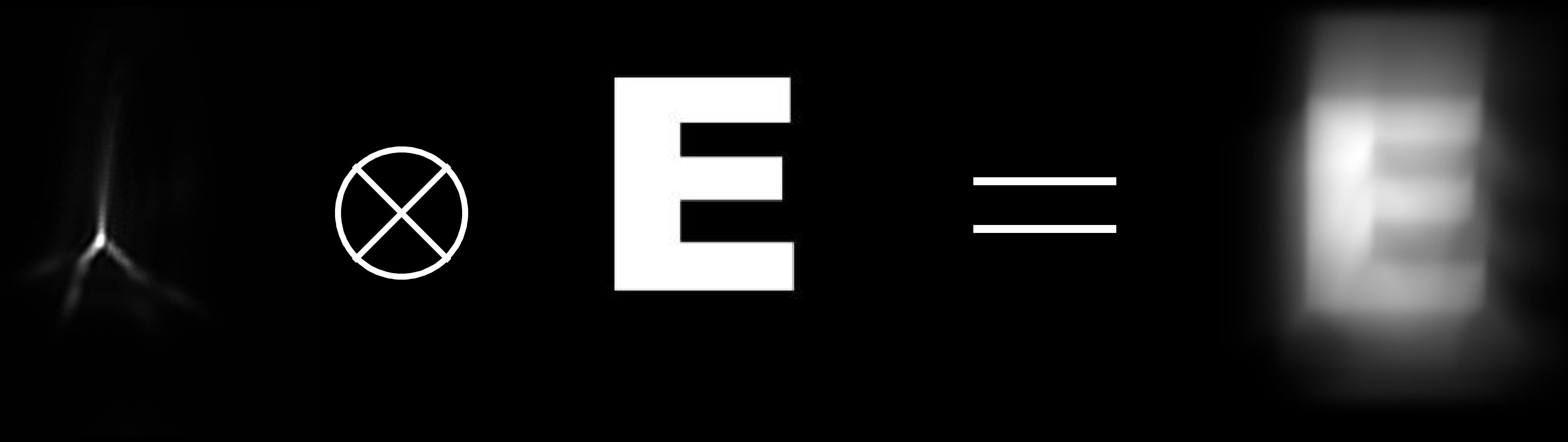
STREHL RATIO

Diffraction-Limited **PSF**

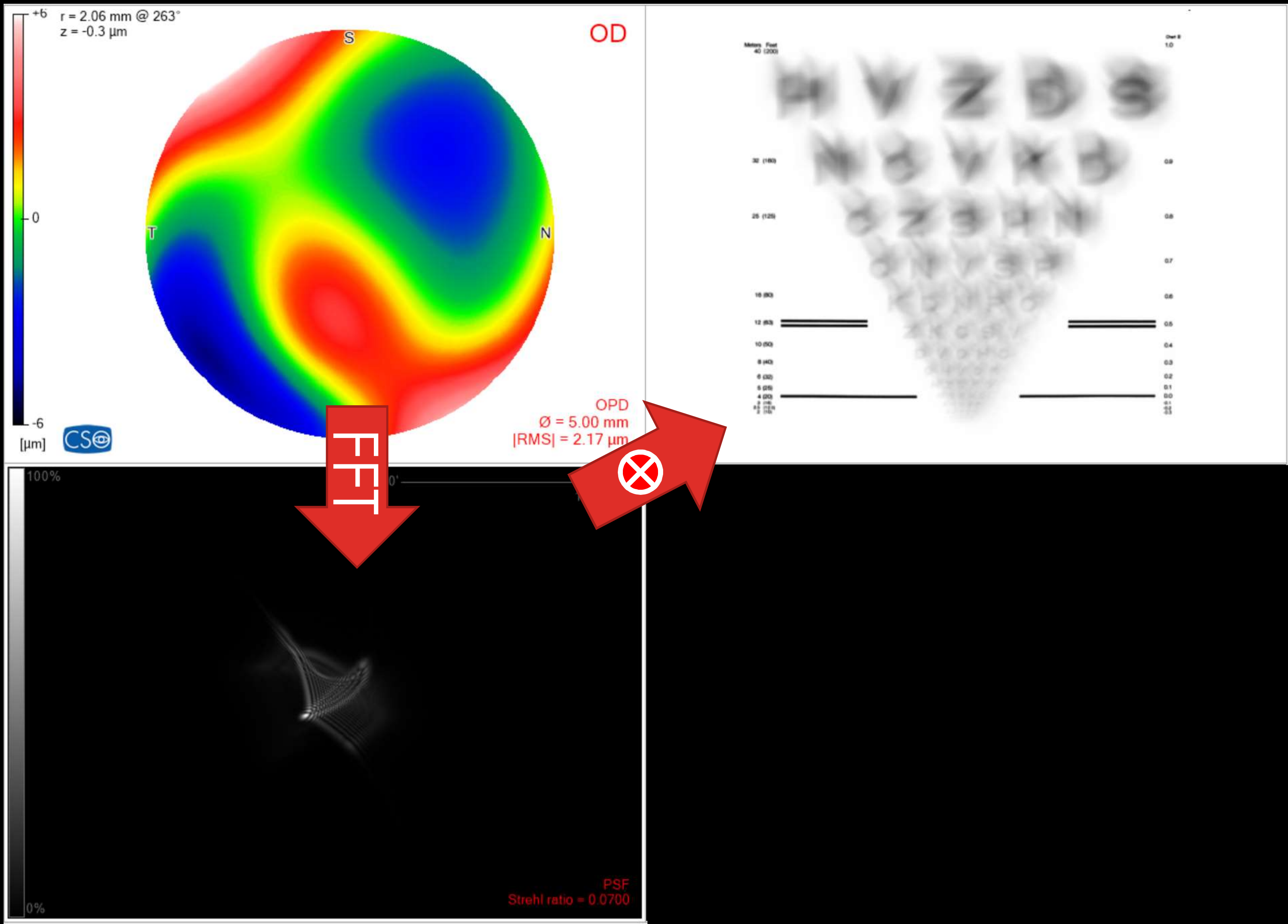
$$\text{Strehl Ratio} = H_{eye} / H_{dl}$$



CONVOLUTION



CONVOLUTION: SIMULATED IMAGES



MTF

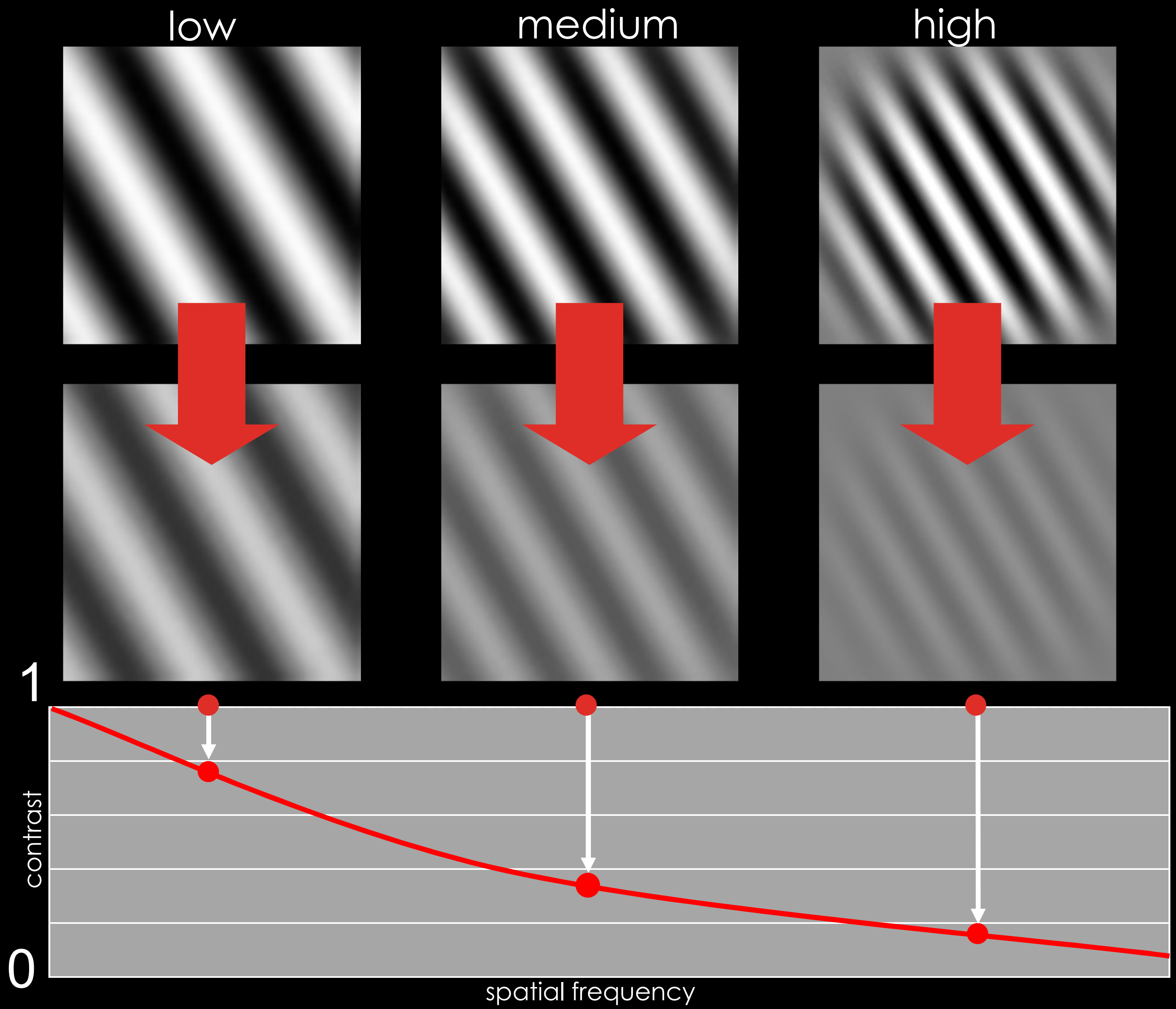
MODULATION TRANSFER FUNCTION (MTF)

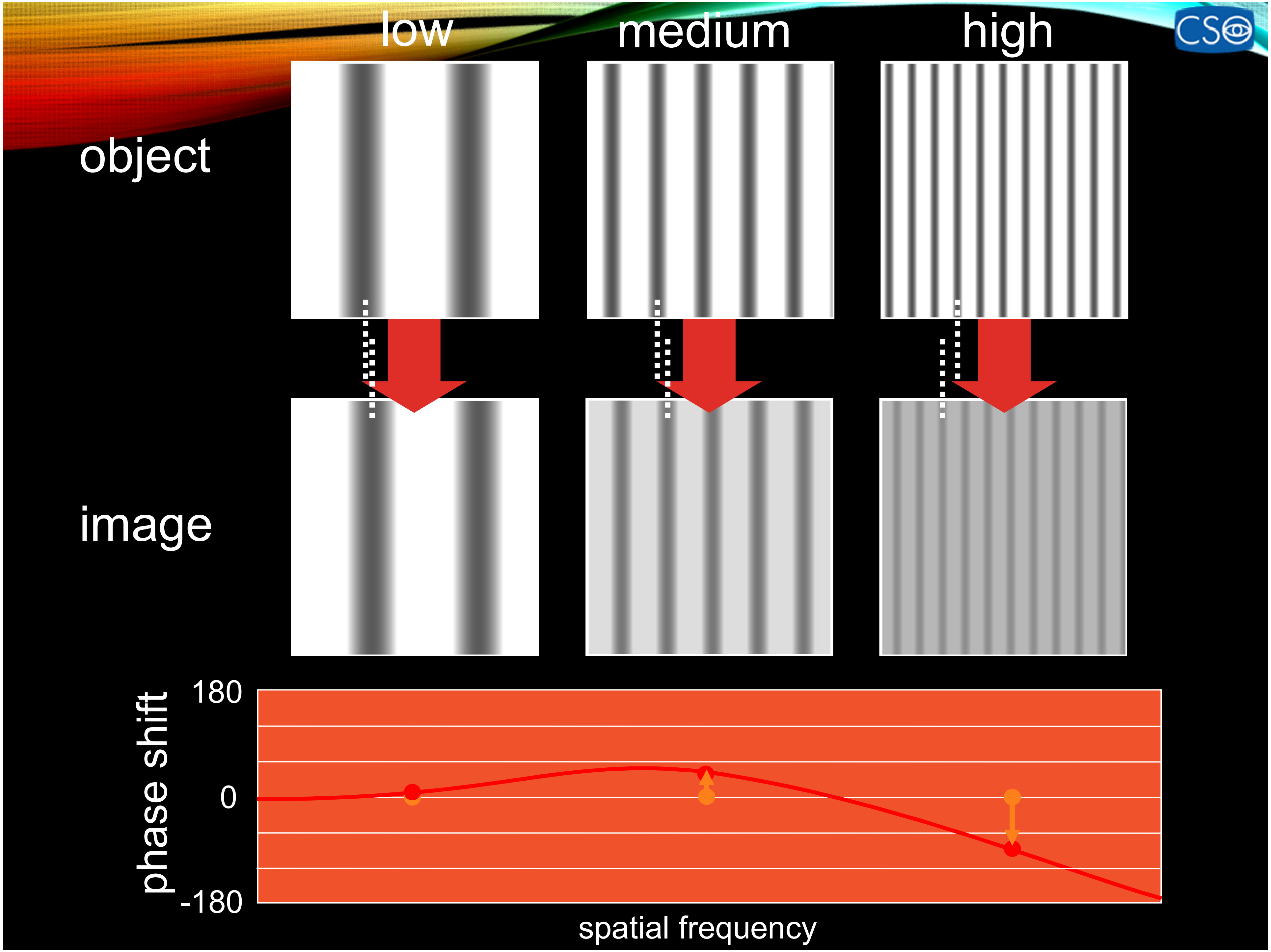
- The Modulation Transfer Function (MTF) indicates the ability of an optical system to reproduce (transfer) various levels of detail (spatial frequencies) from the object to the image.
- Its units are the ratio of image contrast over the object contrast as a function of spatial frequency.
- It is the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

MODULATION TRANSFER FUNCTION (MTF)

object:
100%
contrast

image





low
medium
high
object
image
phase shift
180
0
-180
spatial frequency

PSF, OTF, MTF AND PTF

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

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

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

ABERROMETERS

OCULAR ABERROMETER