A tutorial on higher order aberrations:

What are they?
How are they measured?
What is their clinical relevance?
Can they be corrected?

presented by

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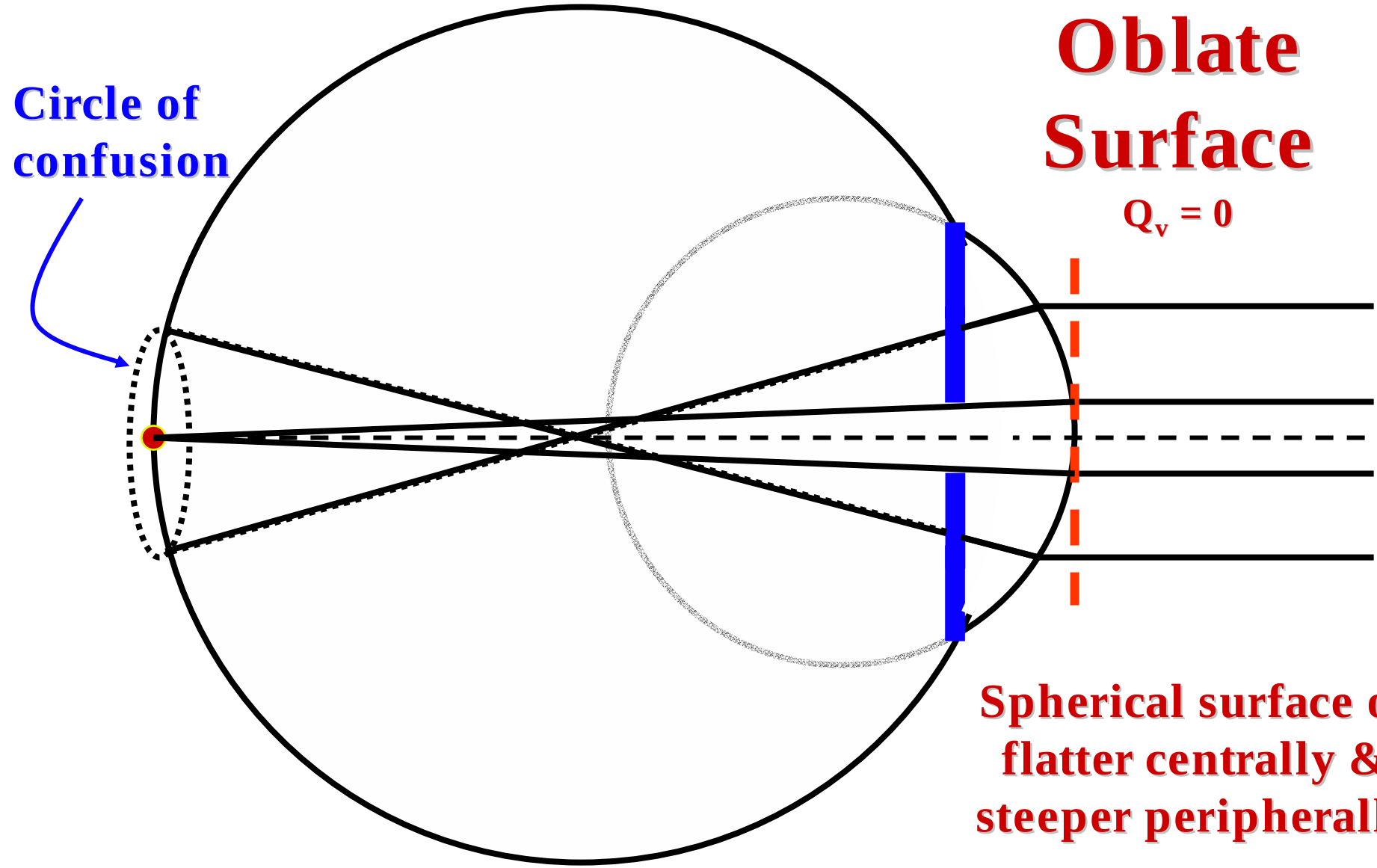
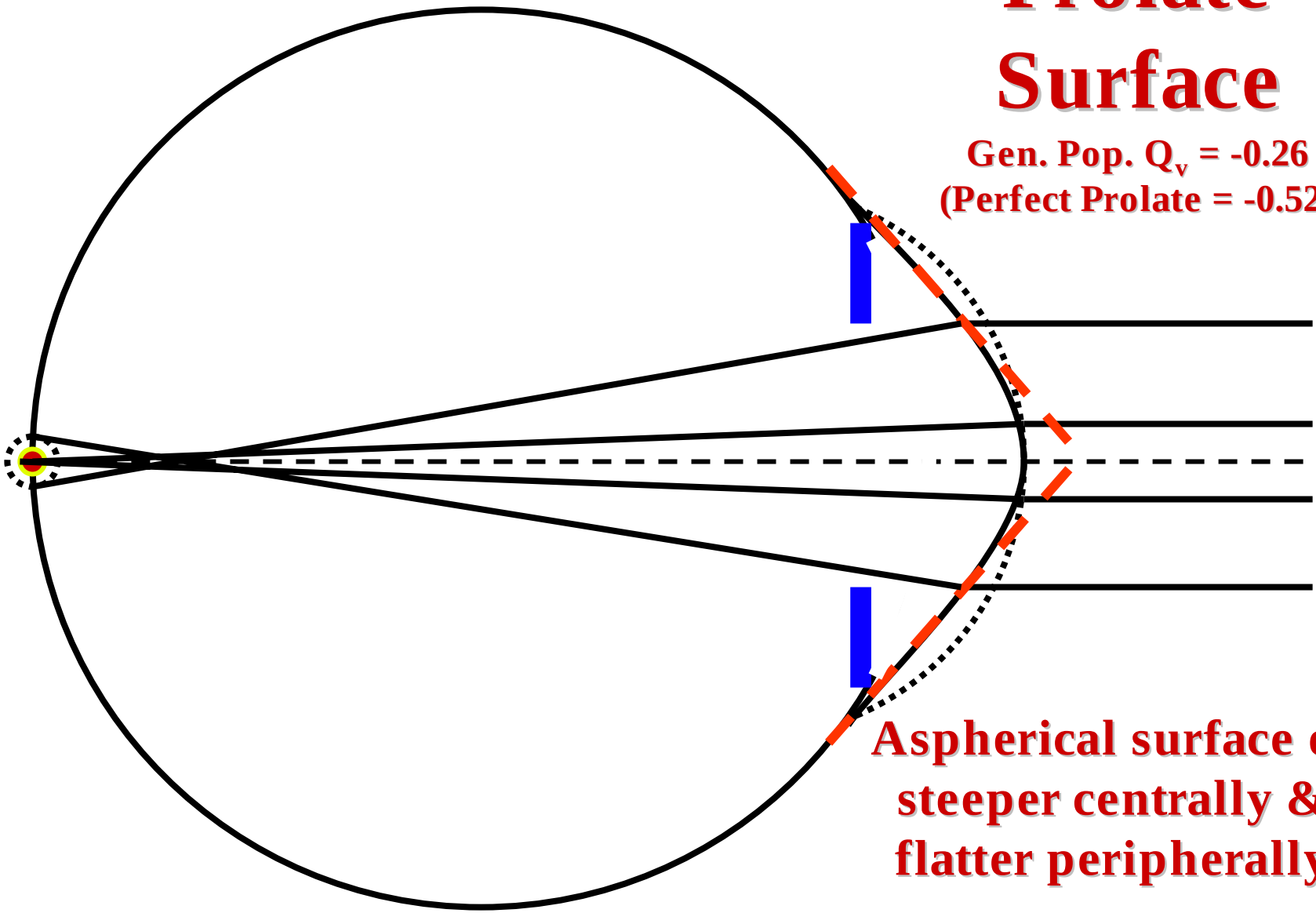
Higher Order Aberrations (HOAs)

1. What are they?
2. How are they measured?
3. What is their clinical relevance?
    a. Little to none
    b. Significant
    c. Unknown
4. Can we correct them?



Prolate Surface

Gen. Pop. Q_v = -0.26
(Perfect Prolate = -0.52)



Aspherical surface or steeper centrally & flatter peripherally

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Traditional Refraction

- **Methods of measurement:**
  - **Traditional subjective and objective refraction for:**
    - **Piston** ***(Plano)***
    - **Prism** ***(Tilt)***
    - **Sphere** ***(Defocus)***
    - **Cylinder** ***(Cylinder)***

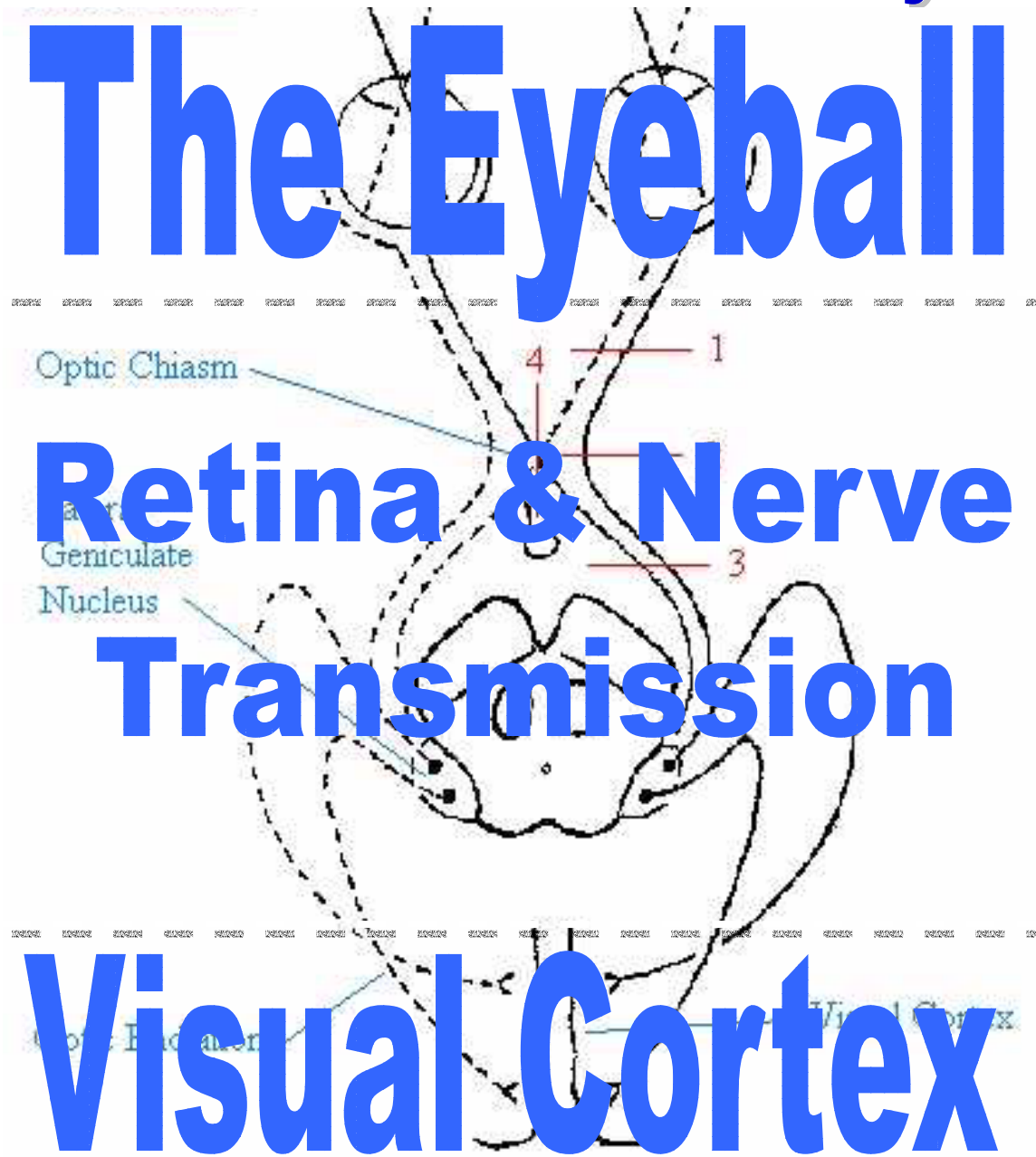
    } = ***First order aberration***

    } = ***Second order aberration***

    } ***Lower order aberrations***
  - **Automated objective refraction**
  - **Computerized subjective and objective refraction**
  - **Keratometry for corneal cylinder**
  - **Corneal topography for corneal cylinder, asymmetry, warpage, etc.**

The human visual system

The Eyeball



Retina & Nerve

Transmission

Visual Cortex

RMS System from "Adaptive Optics"

- RMS deviations *(Root Mean Square)* = $\sqrt{w(r, \varnothing)^2}$
  Measure of aberrations of an optical system
  (Coma, spherical aberrations, distortion, defraction, etc.)
- The lower the RMS, the better the visual acuity
- Lowest potential RMS for the human eye = ~ 0.07*u*
  (*Marèchal's Criterion*)
- An RMS of 0.07*u* can produce a visual acuity of 20/6
  thus,
- The maximum potential visual acuity of human eye

20 / 6…or "SuperVision"

But . . .

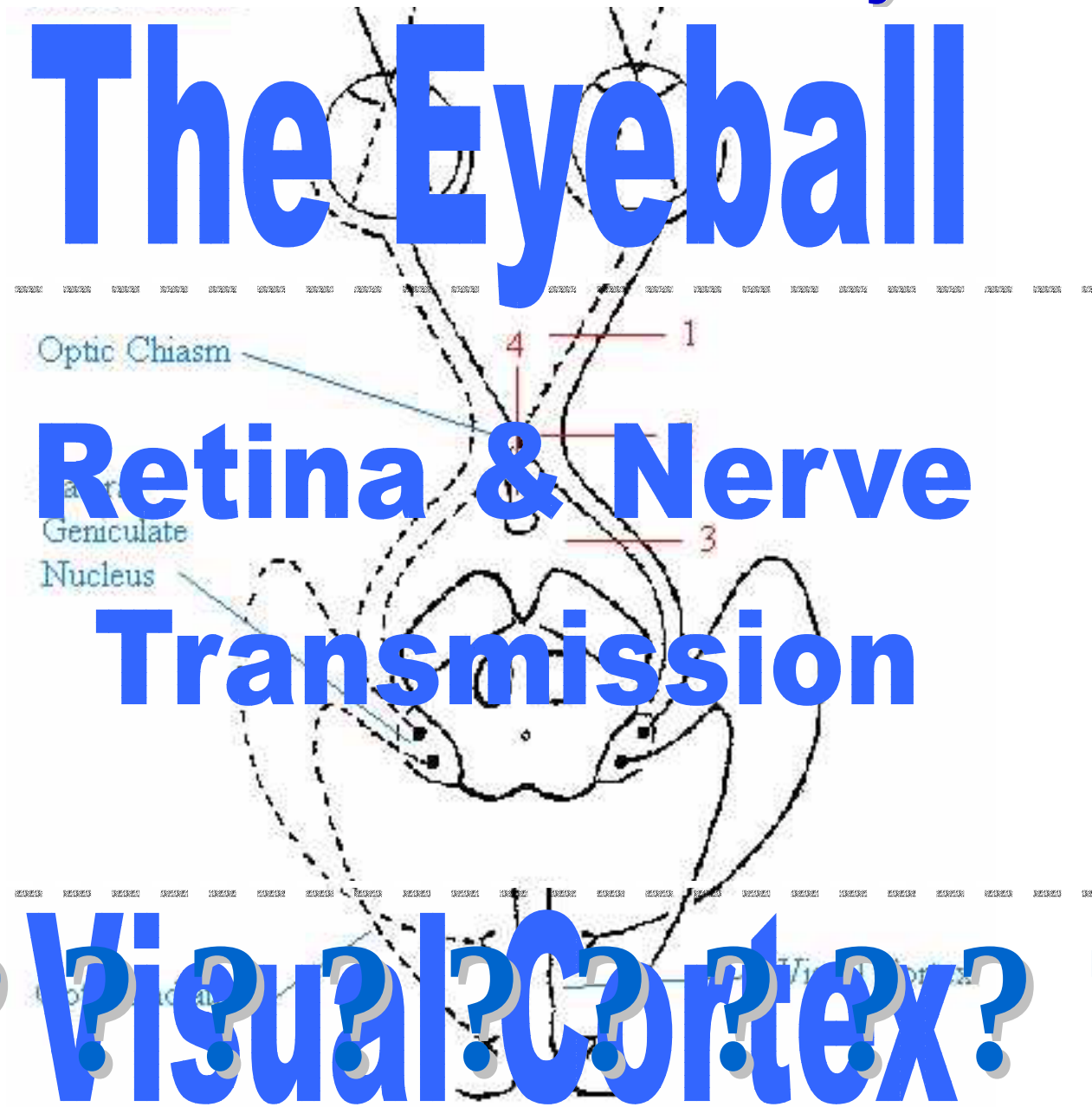
Neural/retinal considerations:

- Number of cones in retina ≡
  ~ 4 to 7 million
- Max. number of cones in the fovea ≡
  ~ 5 million
- Visual acuity resolution threshold for
  ~ 5 million cones ≡ . . .

20 / 8…*or "SuperVision"*

The human visual system

The Eyeball



Retina & Nerve

Transmission

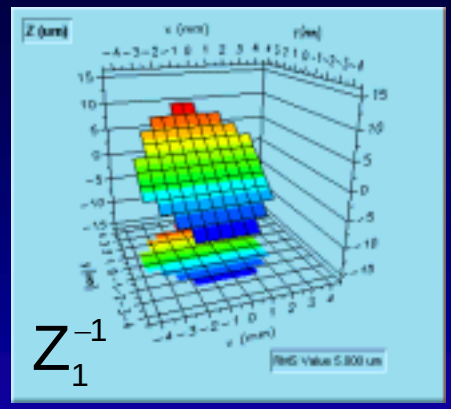
? ? ? Visual Cortex ? ? ?

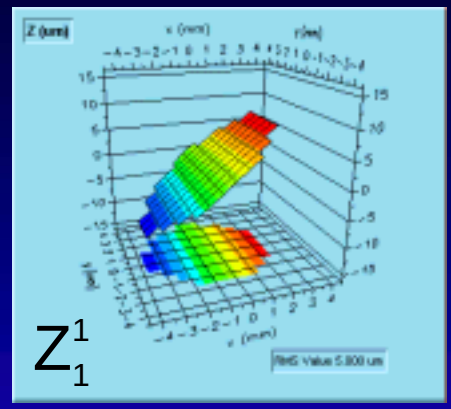
Refractive issues

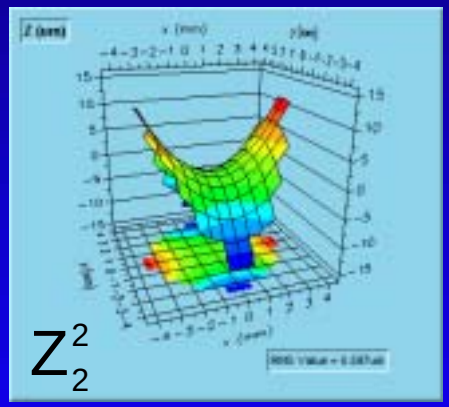
- Zernike's Polynomials (Coefficients)

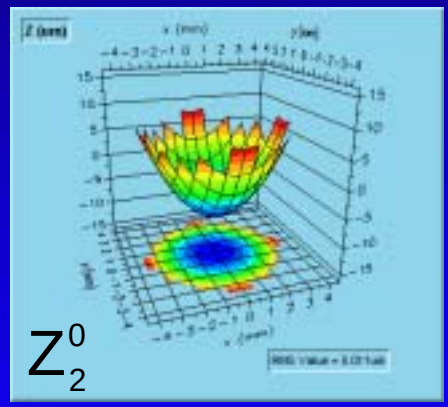
RMS values mathematically converted to 3 dimensional models describing the shape of a specific aberration.

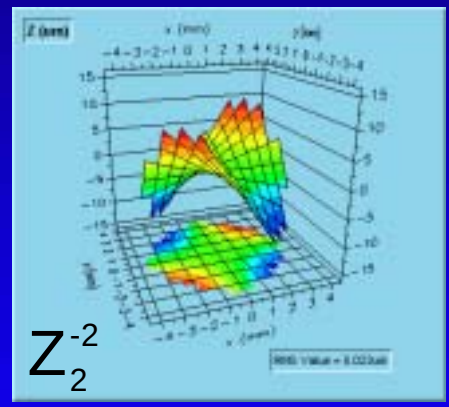
Zernike's Polynomials as *Wavefront Maps*

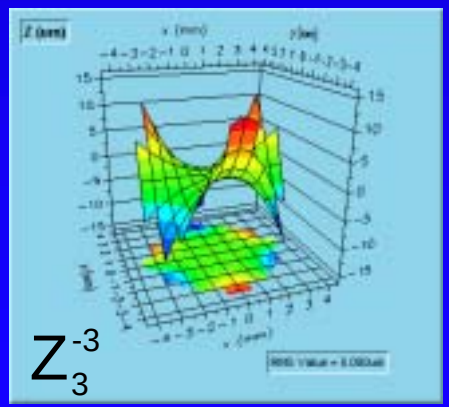


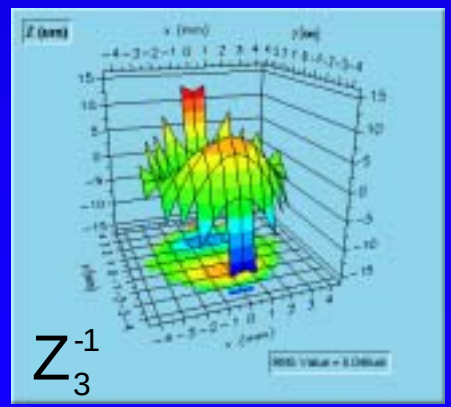


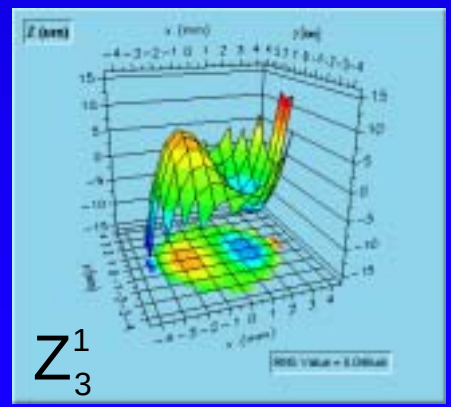


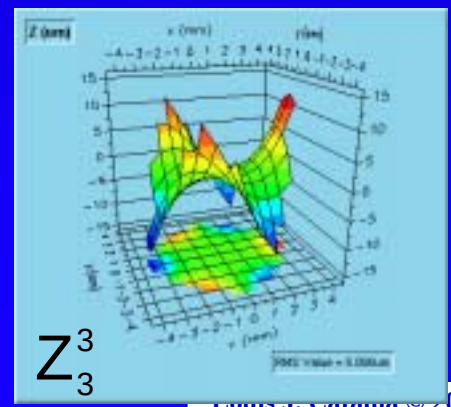












Refractive issues

- **Zernike's Polynomials (Coefficients)**

1st Order = Tilt (prism)

2nd Order = Defocus (sphere) and cylinder

Lower order aberrations (80 to 83%)

3rd Order = Coma and trefoil

4th Order = Spherical aberration and quadrefoil

5th Order = Distortions/irreg. astigmatism

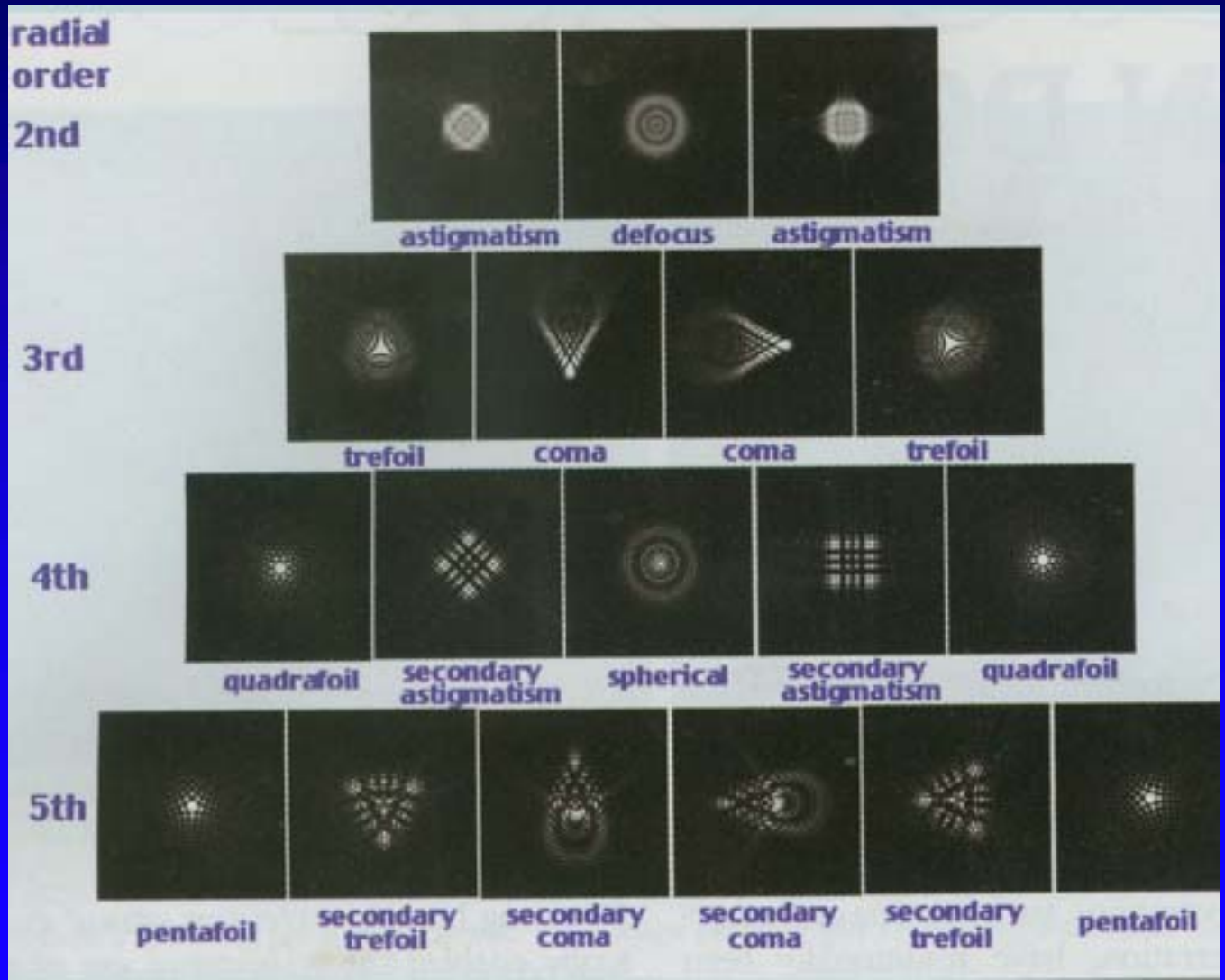
6th through 8th Order = Increasing levels of irregular astig.

Higher order aberrations (17 to 20%)

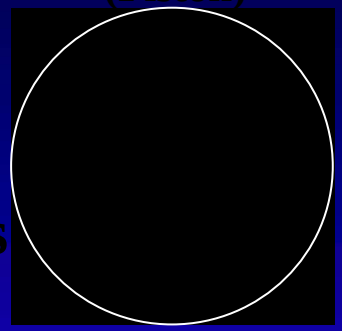
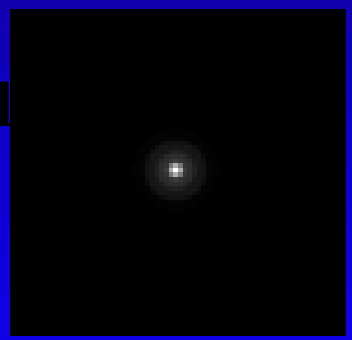
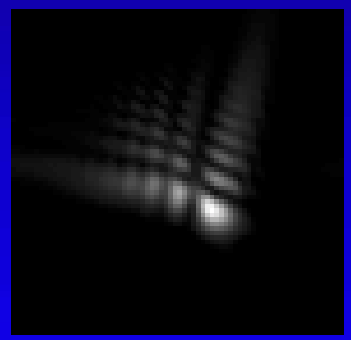
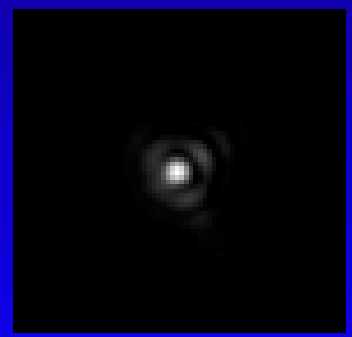
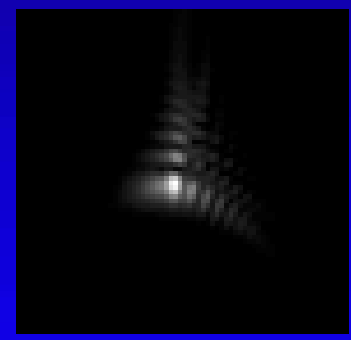
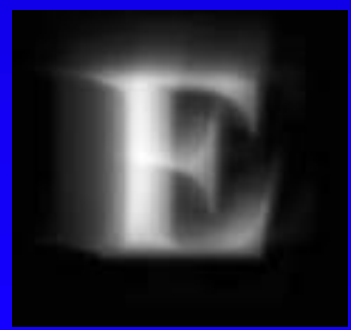
- **Over 65 total aberrations identified to 8th order**
- **Measured in RMS units & "point spread function"**

Point Spread Function

Describes how the light from a single point would be scattered on the retina by the patients optical system



Three Views of Higher Order Aberrations (HOAs)

	Perfect eye (Piston)	Coma	Spherical aberration	Quadrefoil
Zernicke Polynomials				
Point Spread Function (PSF)				
Retinal Image				

Qualitative effects of the most common higher order aberrations

Coma & Trefoil (3rd order) & iregular astigmatism

- Reduced mesopic vision
- Flare
- Monocular diplopia

Spherical aberration & Quadrefoil (4th order)

- Reduced mesopic vision
- Glare, halos, starbursts
- Reduced contrast sensitivity

Refractive issues

- **Measurements:**

Lower order aberrations

(Prism, sphere and cylinder)

Represent ~ 80% of total aberrations

- **Traditional refraction**
  - **Subjective**
  - **Objective**
- **Automated refraction**
- **Computerized refraction**
- **Keratometry**
- **Corneal topography**
- ***Goal = 20/20 or ~ 80%***

Higher order aberrations

- **Wavefront analysis**
  - **Measures lower and higher order aberrations**
  - **Coma, sph. aberrations, irregular astigmatism, etc.**
  - **Objective (c subjective refinement capability)**
  - **Measures to 0.05*u* (0.005 D)**

(3*u* = ~ 0.25 diopter)

- ***Goal = 20/8 or 100%***

Higher Order Aberrations (HOAs)

1. What are they?
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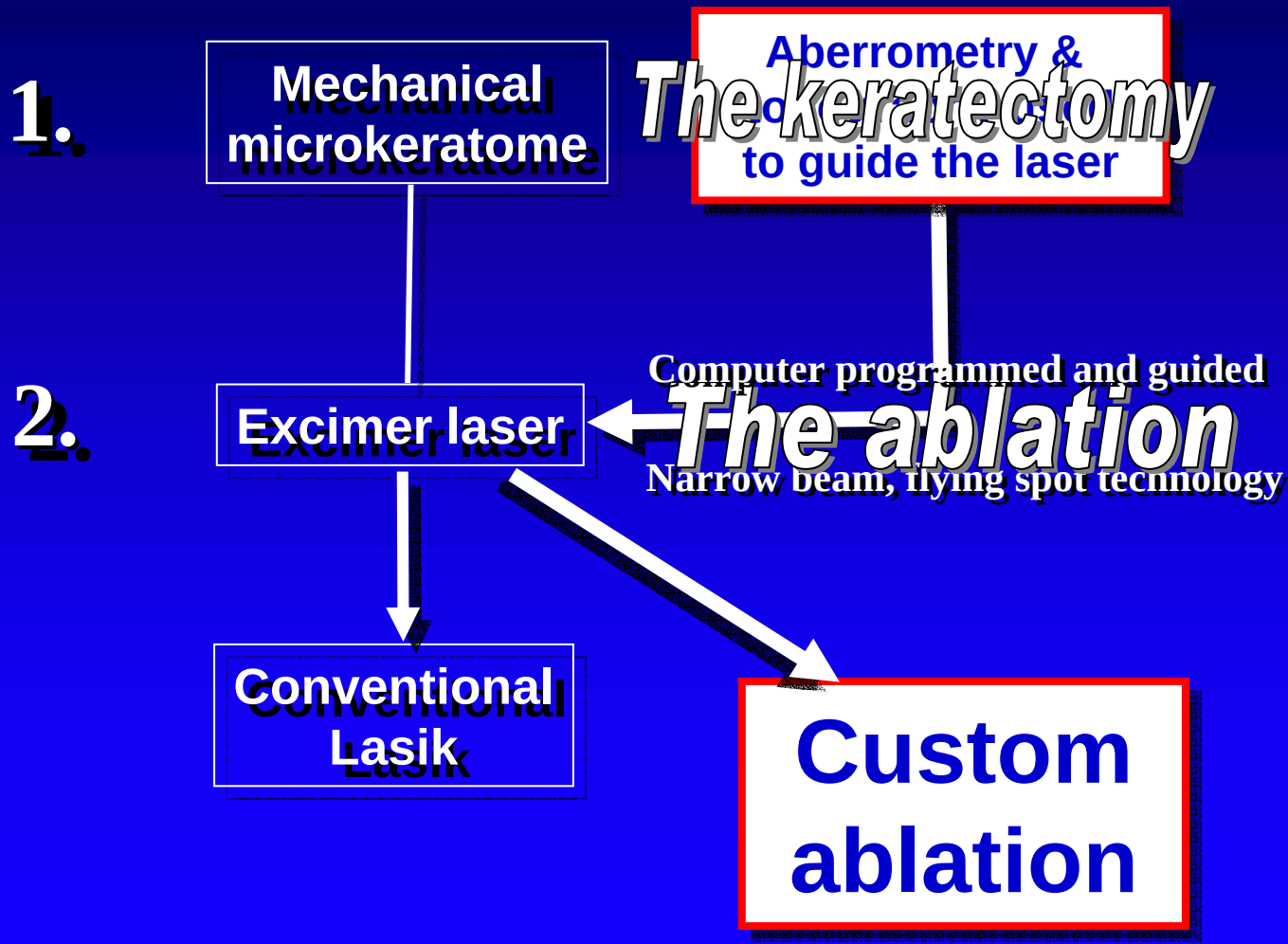
3. What is their clinical relevance?
   a. Little to none *Thibos, Lipshitz, Holladay, etc.*
   b. Significant *Durrie, Krueger, "Catania re: Dx"*
   c. Unknown *Williams, Applegate, Klyce, etc.*
4. Can we correct them?

Laser Vision Correction & Wavefront Guided Custom Ablation



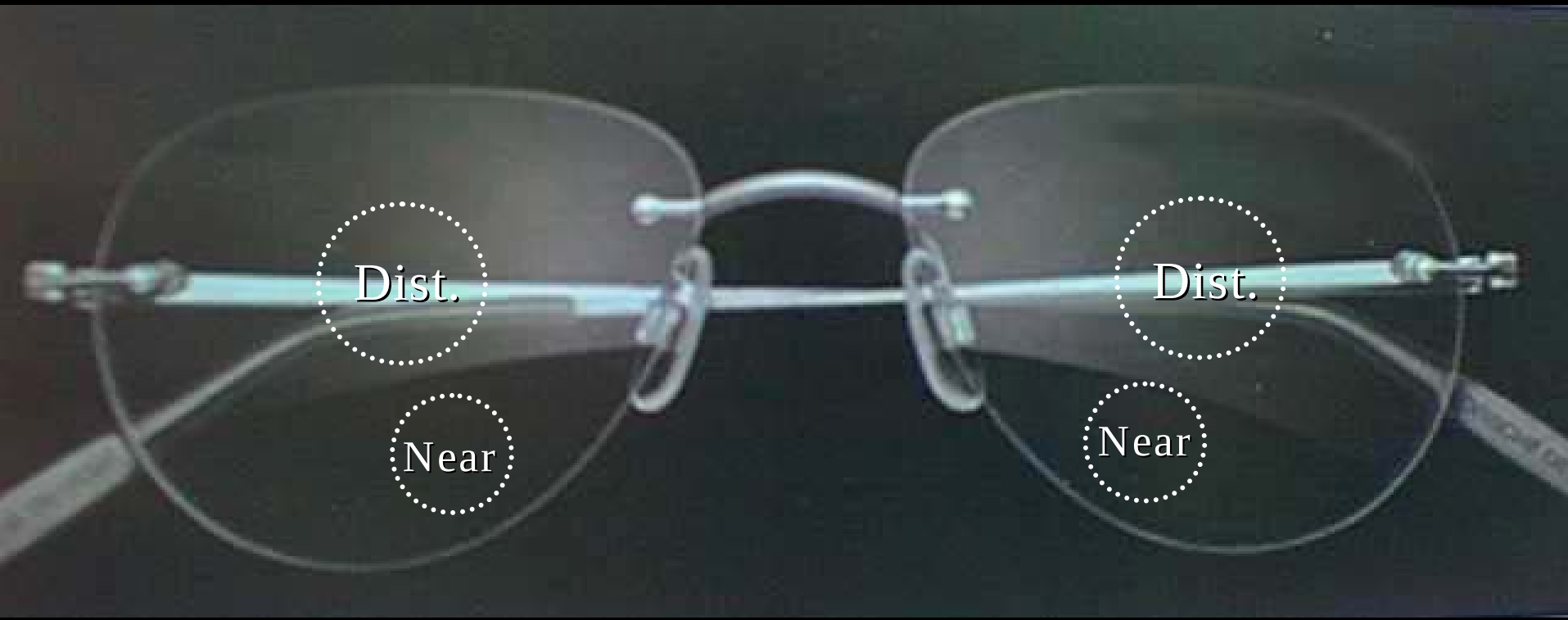
BUT…

- **Soft tissue, corneal correction heals (“remodels”) at approximately 5*u* accuracy (squamous epith. cell diam.).**
- **HOA correction requires > 2*u* accuracy (> 0.25 D).**
- ***Thus*, correcting HOAs with refractive surgery may be a biological impossibility.**

BUT…

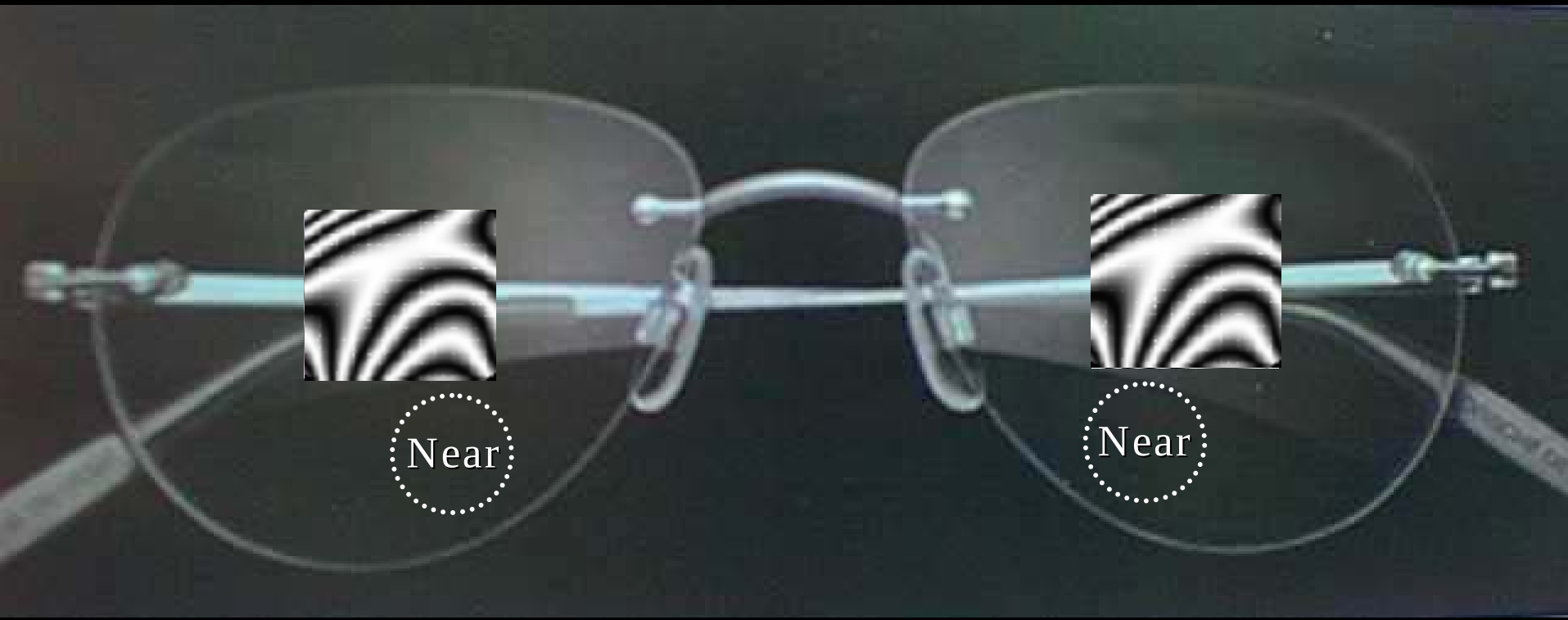
- **Synthetic materials (e.g., glass, plastic, silicone, etc.) *do not heal*. *S*uch materials can be fabricated to HOA correcting levels and *retain* their correction.**
- **Perhaps such materials in the form of spectacles and contact lenses can accomplish HOA correction.**
- **This is the *Ophthonix* concept.**

Wavefront programmed and constructed HOA correcting, “intelligent” spectacle lenses



Wavefront programmed and constructed HOA correcting spectacle lens

Ophthonix Z-Lens




Exciting times ahead
in vision care and
for our profession!


Thank you
Good luck and Godspeed
LCatania@bellsouth.net

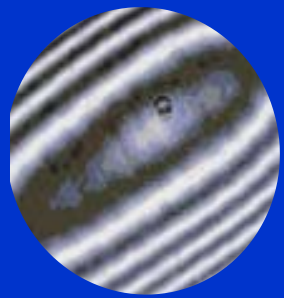
Ophthonix Vision Optimization

The eye

Many localized imperfections

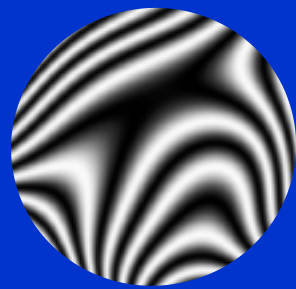
"Optical Fingerprint"

Today's lenses



Perfect lens trying to match imperfect eye

Ophthonix



Totally customized, one-of-a-kind match to eye's individual "fingerprint"

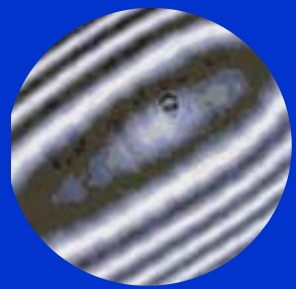
Ophthonix Vision Optimization

The eye

Many localized imperfections

"Optical Fingerprint"

Today's lenses



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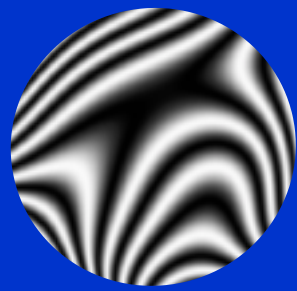
Ophthonix



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