Phakometry

- Phako- root word meaning lens, usually referring to the natural crystalline lens of the eye (Hoffman, Pocket Glossary of Ophthalmologic Terminology p68)
- -metry - measurement of

Ways of Measuring the Crystalline Lens

- In vitro -
  - remove the lens from the eye
  - freeze
    - measure curvatures
    - take slices
      - measure index of slices
- Problems -
  - shape and properties of lens change (tends to shrink and cloud up) due to lack of circulation from body

…Continued

- In vivo
  - ultrasound
    - can measure curvatures and thicknesses but is slow and touches the cornea
  - optical coherence tomography
    - measures curvatures and thicknesses
    - also somewhat slow
  - purkinje images
    - measures curvatures
    - allows measurement while eye is viewing a target (can look at accomodation variations)

Purkinje Images

- Fresnel reflections at discontinuities in index of refraction
- In visual optics these are called Purkinje-Sanson reflections.
- PI - air/cornea (or tear film)
- PII - posterior cornea/aqueous
- PIII - aqueous/anterior lens
- PIV - posterior lens/vitreous

Calculating Purkinje Images

- Trace rays from an object point through the eye to the surface that is creating the Purkinje.
- Reflect the rays at that surface.
- Trace the reflected rays back to the cornea.
- Find the magnification and position of the virtual image formed by the rays leaving the cornea.

Ray Tracing Reflective Surfaces

- Power = (n’-n)/R
- On reflection, n and t become negative (τ = n*t remains positive)

Power is then (-n-n)/R=-2n/R

Photometry of Purkinje Images

- Reflectance

$$\tilde{n} = \left[\frac{(n_1 - n_2)}{(n_1 + n_2)}\right]^2$$

- PI

$$\tilde{n}_1 = \left[\frac{(1 - 1.377)}{(1 + 1.377)}\right]^2 = 0.025 = 2.5\%$$

- PII

$$\tilde{n}_2 = \left[\frac{(1.377 - 1.337)}{(1.377 + 1.337)}\right]^2$$
$$= 2.17 * 10^{-4} = 0.02\%$$

- PIII

$$\tilde{n}_3 = \left[\frac{(1.337 - 1.42)}{(1.337 + 1.42)}\right]^2$$
$$= 9.06 * 10^{-4} = 0.09\%$$

- PIV

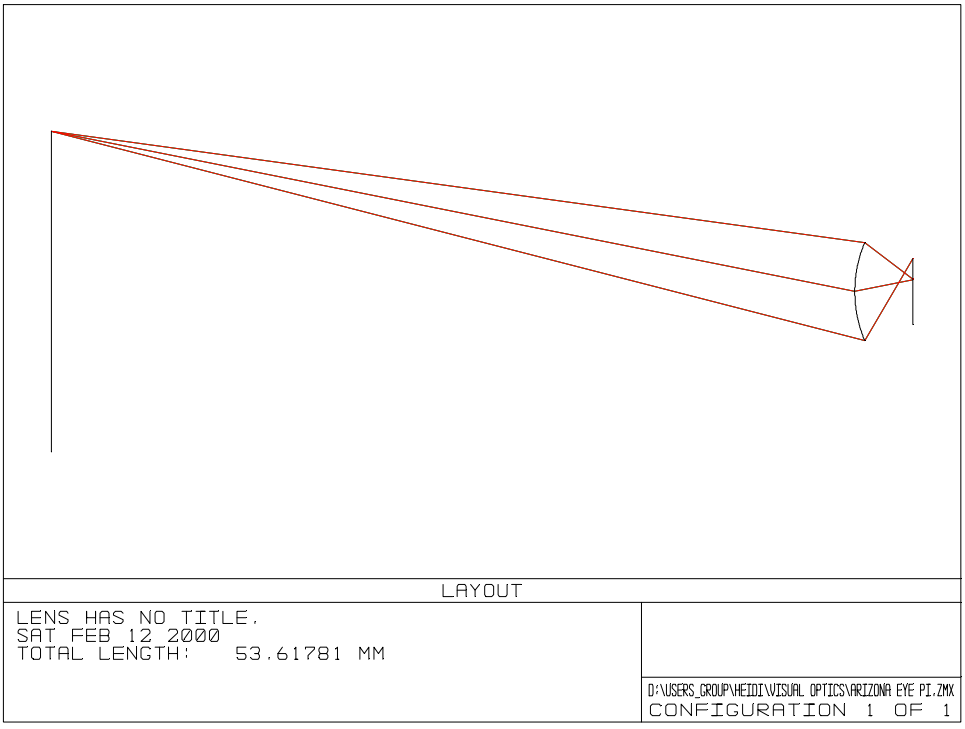
$$\tilde{n}_4 = \left[\frac{(1.42 - 1.336)}{(1.42 + 1.336)}\right]^2$$
$$= 9.29 * 10^{-4} = 0.09\%$$

Sample Purkinjes

- Object height 10 mm
- Object distance 50 mm
- Using Arizona Eye model
- Image locations relative to anterior corneal vertex

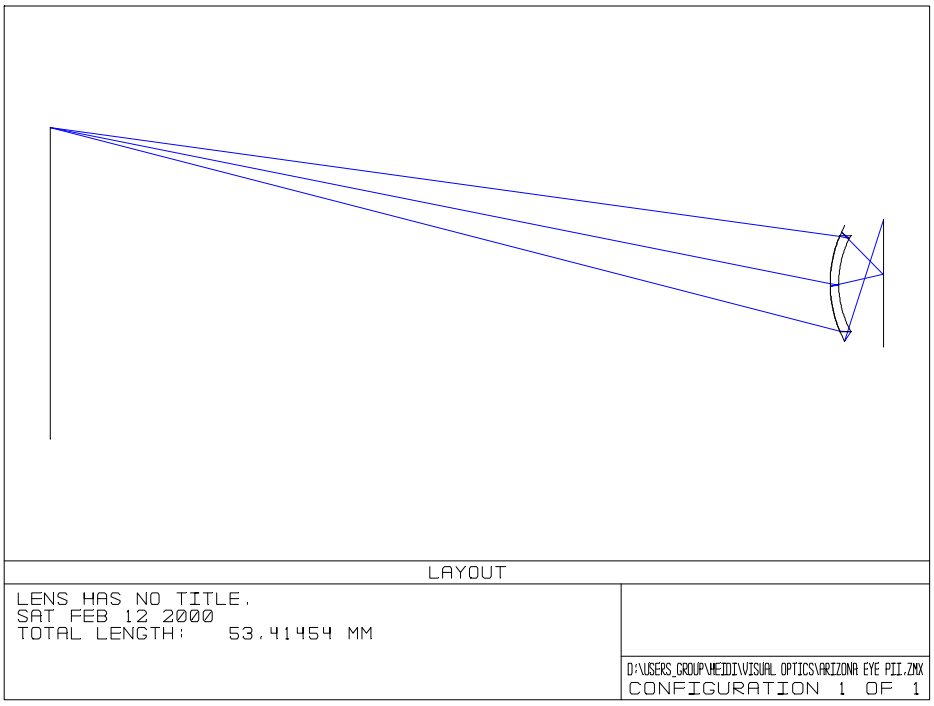
PI

- Reflection from cornea
- Virtual, erect image located 3.6 mm behind cornea
- Reflected illumination 2.5%
- Magnification = 0.072



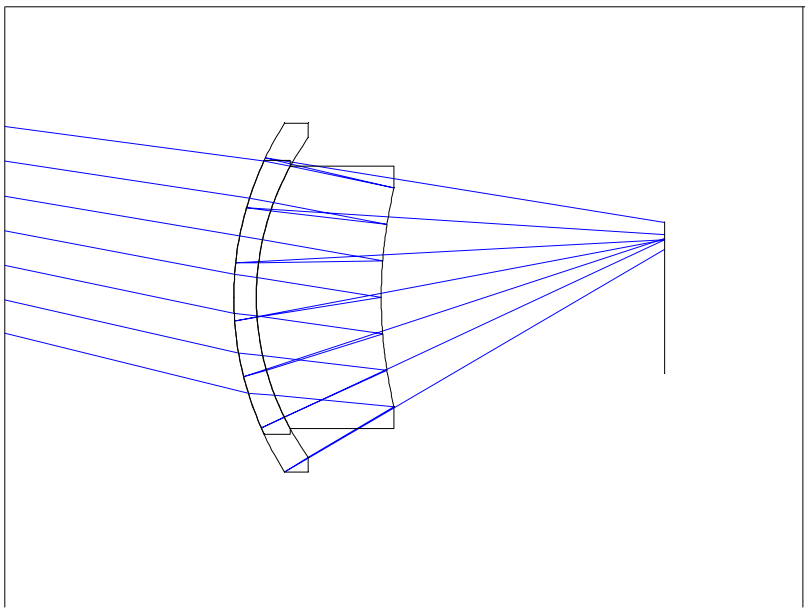
PII

- Refracts at anterior cornea, reflects at posterior cornea, refracts at anterior cornea
- Virtual, erect image 3.41 mm behind cornea
- Reflectance 97.5%*0.02%*97.5% = 0.019%
- Magnification = 0.06



PIII

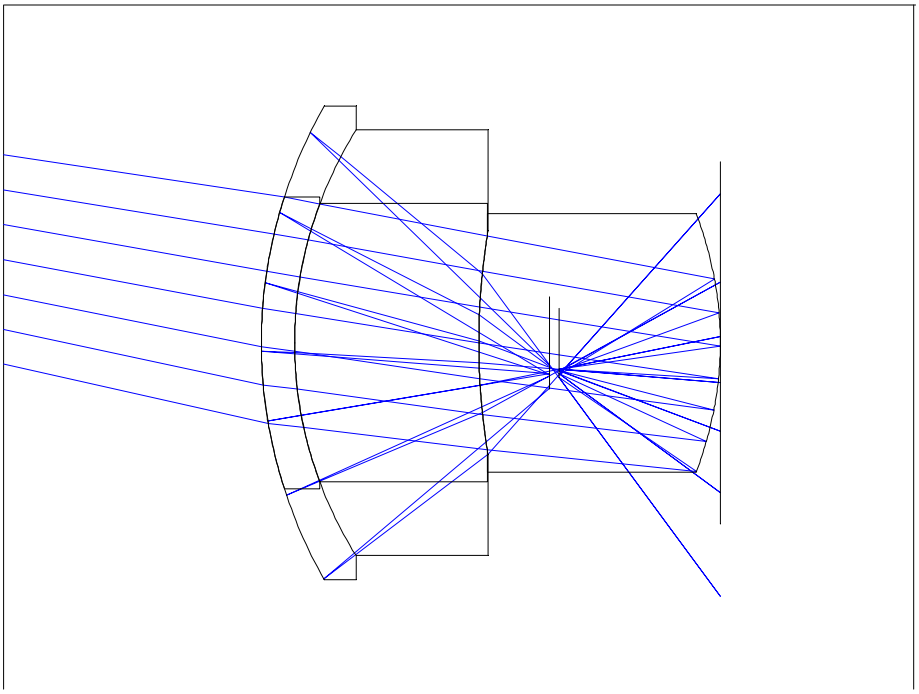
- Refracted through cornea, reflected at posterior lens, refracted back through cornea
- Virtual, erect image 10.5 mm behind cornea
- Reflectance 97.5% *99.98% *0.09% *99.98% *97.5%=0.086%
- Magnification 0.14 (about 2x the others!)



PIV

- Refracted to back of lens, reflected by posterior lens, refracted back to anterior cornea
- Real, inverted image formed!! 4.92 mm behind cornea
- We view the virtual image of this real image. The virtual image is 4.77 mm behind the cornea
- Reflectance 97.5% *99.98% * 99.91% *0.09% * 99.91% * 99.98% * 97.5% = 0.085%
- Magnification (for observed virtual image) -0.05

PIV



#	Type	Comment	Curvature	Thickness	Glass	Semi-Diameter	Conic
0	STANDARD	Object	0.00000	50.00000		10.00000	0.00000
1	STANDARD	Anterior Cornea	0.12821	0.55000	377567	2.42100	-0.25000
2	STANDARD	Posterior Cornea	0.15385	3.05000	337496	2.30556	-0.25000
3	STANDARD	Anterior Lens	0.09066	4.00000	420480	1.77398	-4.30000
4	STANDARD	Posterior Lens	-0.17483	-2.67538	MIRROR	2.13974	-1.17000
5	STANDARD	Dummy Real Image	0.00000	2.67538		0.57155	0.00000
6	STANDARD	Dummy	0.00000	-4.00000		3.00000	0.00000
7	STANDARD	Anterior Lens	0.09066	-3.05000	337496	1.85558	-4.30000
8	STANDARD	Posterior Cornea	0.15385	-0.55000	377567	3.52513	-0.25000
9	STANDARD	Anterior Cornea	0.12821	4.77204		3.92438	-0.25000
10	STANDARD	Virtual Image	0.00000	0.00000		0.76234	0.00000

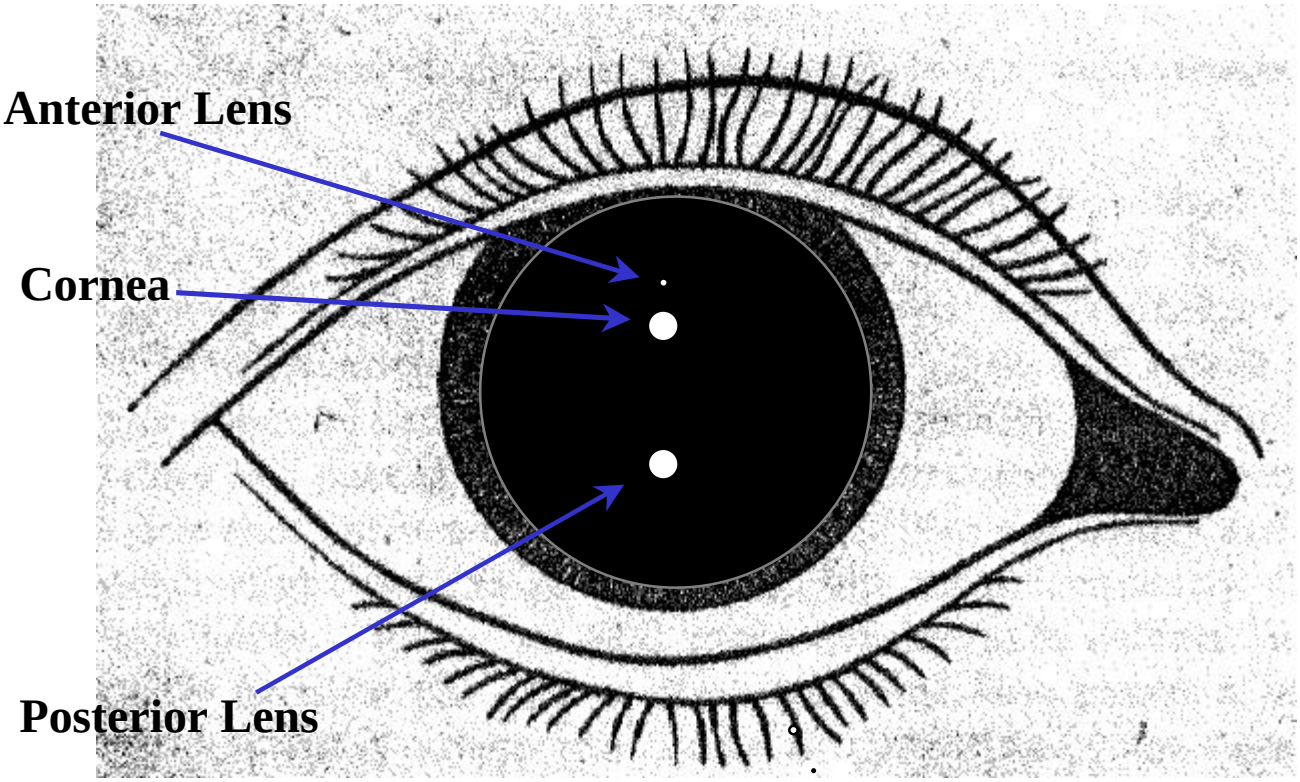
Summary of Purkinje Images

	Location	Magnification	Reflectance
P I	3.6 mm	0.072	2.5%
P II	3.41 mm	0.06	0.019%
P III	10.5 mm	0.14	0.086%
P IV	4.77 mm	-0.05	0.085%

Using Purkinje Images

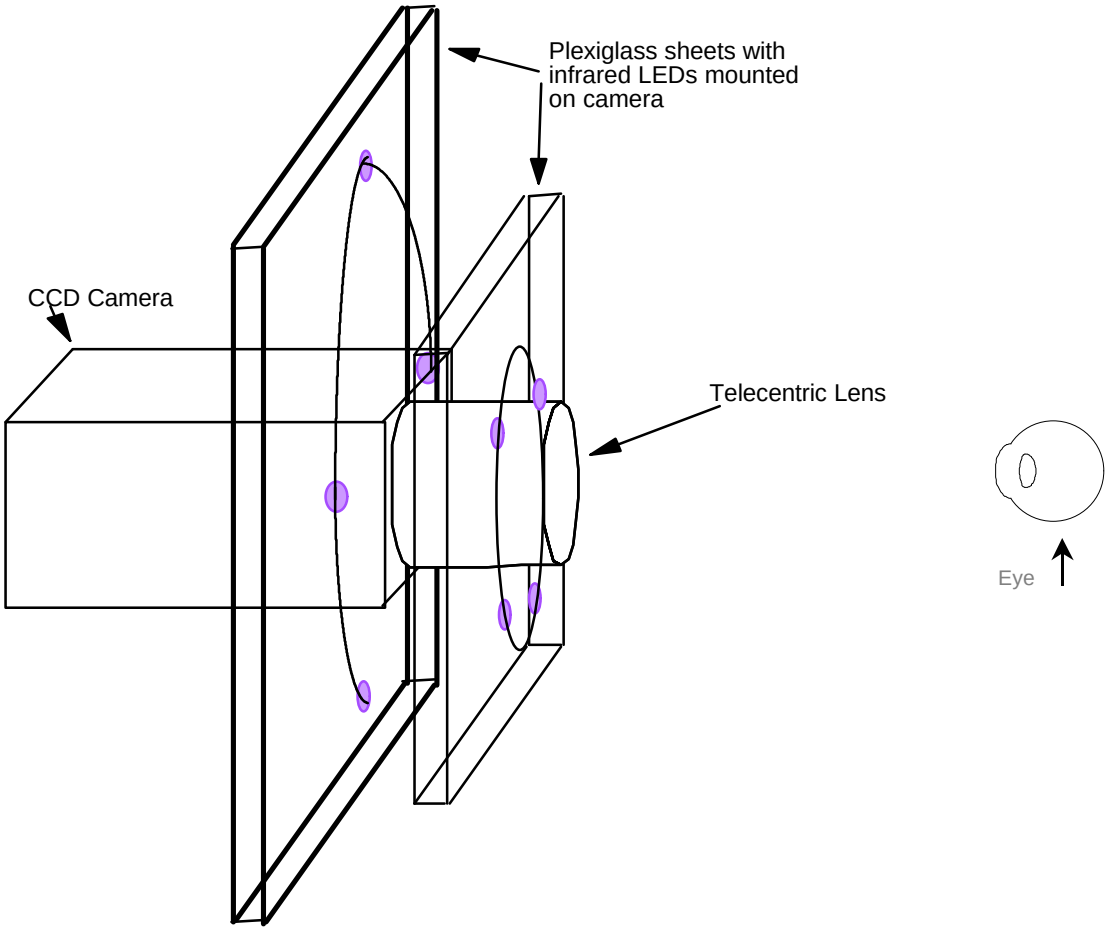
- Generate Purkinjes by using point sources
- Sources are generally used in pairs or more
- Measure the distance of the Purkinje from the center of the distribution of sources
- The distance gives you the relative curvature of the surface that created the reflection

Reflex Images

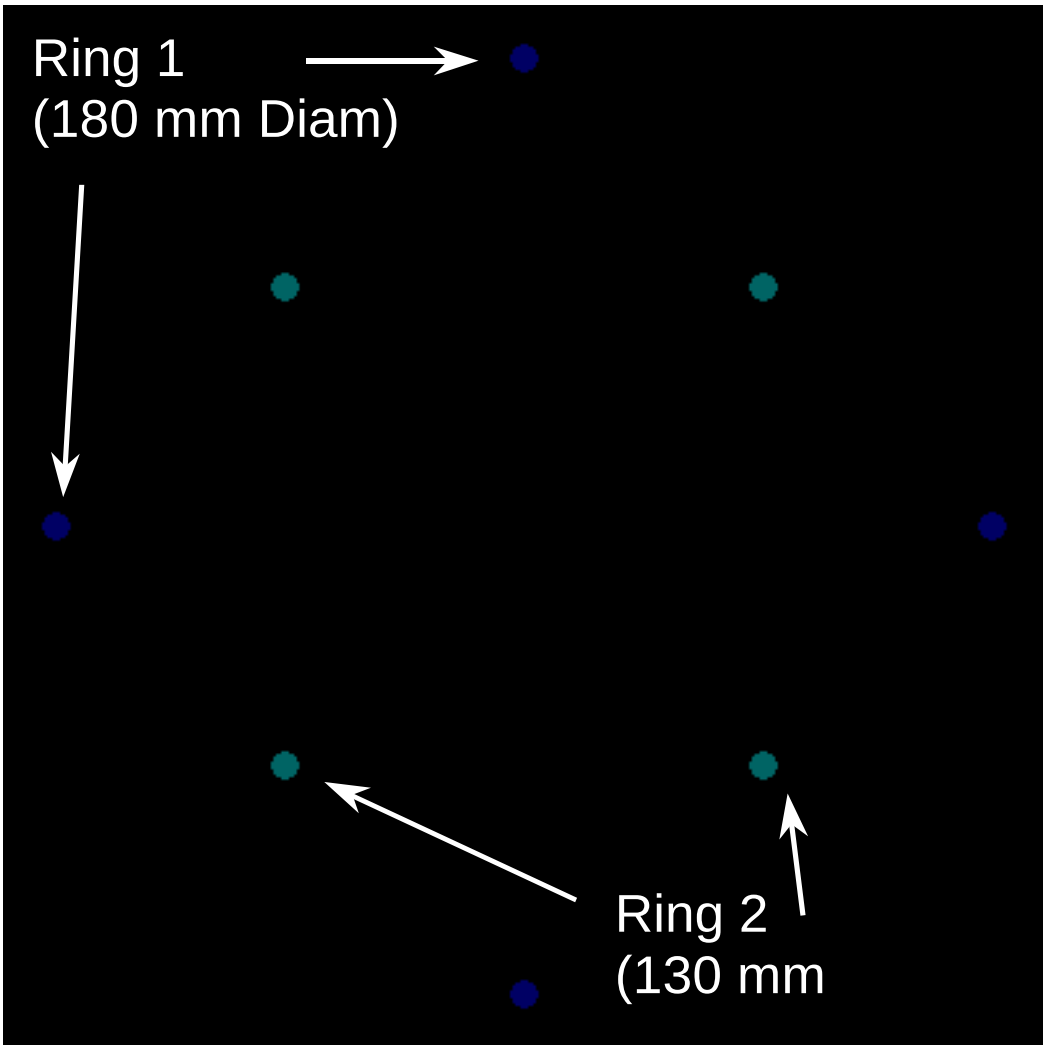


Experimental Setup

- CCD camera with telecentric lens set to fixed focus distance.
- Two rings of infrared LEDs mounted on camera.
- Plexiglass sheets separated by 20 mm.



Simulated Ring Object



Simulated Image

640 Pixels (6.59 mm)

480 Pixels (4.95mm)