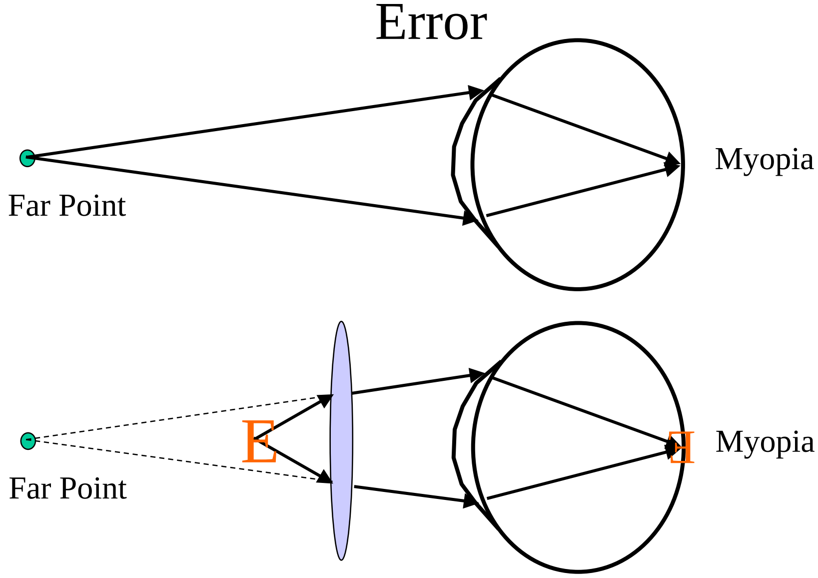
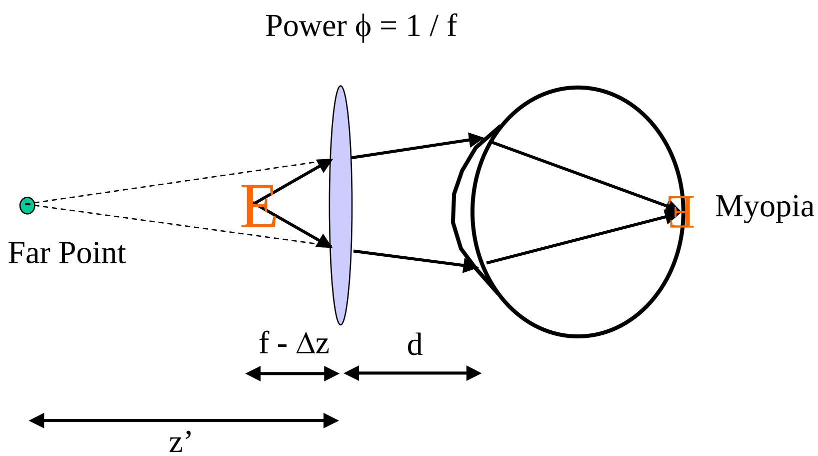
Optometer

Subjective Assessment of Refractive Error



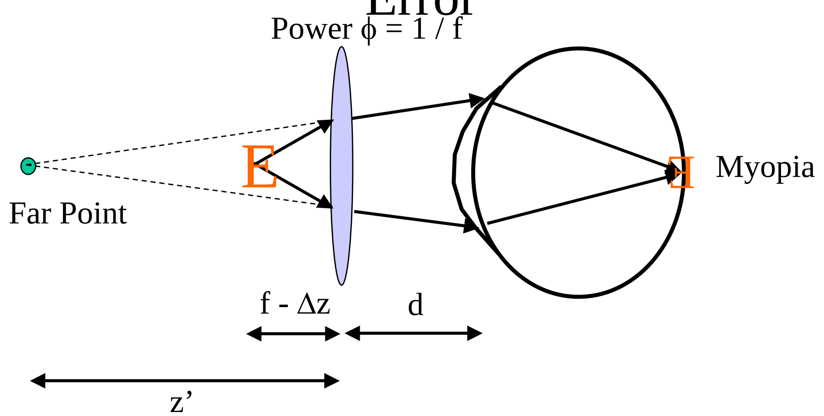
Subjective Assessment of Refractive Error



Subjective Assessment of Refractive Error

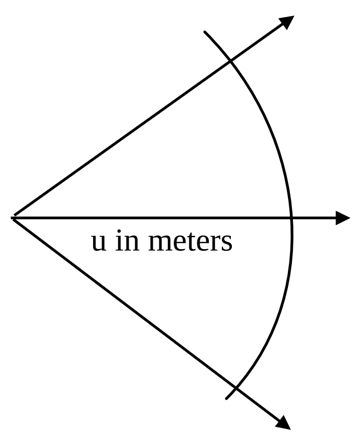
- For $\Delta z = 0$, the light emerging from the lens is collimated (i.e. object at infinity)
- For $\Delta z > 0$, the light emerging from the lens is diverging. The object appears in front of eye, so will be in focus for myopes.
- For $\Delta z < 0$, the light emerging from the lens is converging. The virtual image is behind the eye, so will be in focus for hyperopes.

Subjective Assessment of Refractive Error



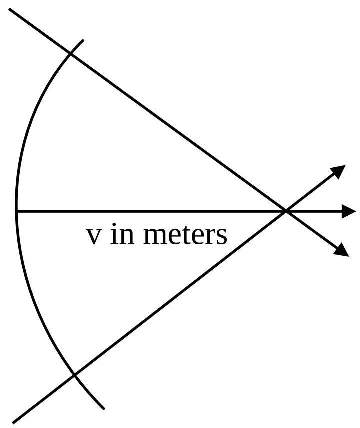
$$\frac{1}{z'} + \frac{1}{f - \Delta z} = \phi \quad \Rightarrow \quad z' = -\frac{1 - \phi \Delta z}{\phi^2 \Delta z}$$

Vergence - Diverging Beam



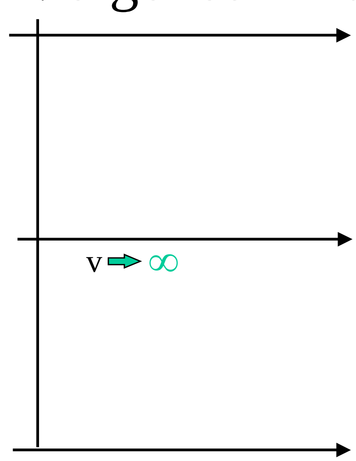
U = -n/u Diopters

Vergence - Converging Beam



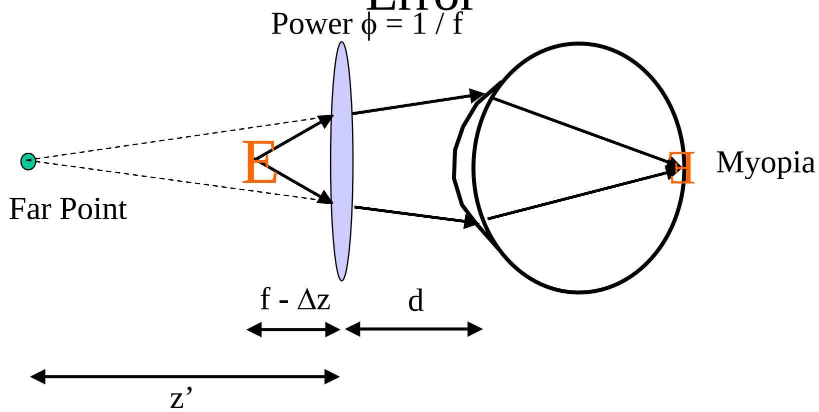
$V = +n/v$ Diopters

Vergence - Plane wave



$V = n/\infty = 0$ Diopters

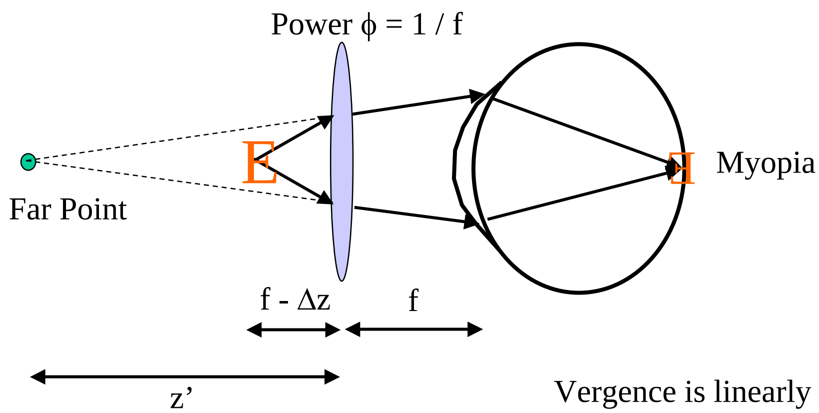
Subjective Assessment of Refractive Error



$$\text{Vergence} = -\frac{1}{d - z'} = -\frac{\phi^2 \Delta z}{1 - \phi \Delta z (1 - \phi d)}$$

Badal Optometer

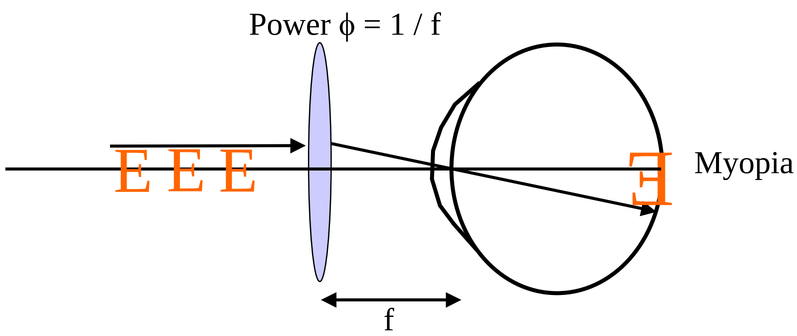
SPECIAL CASE: d = f



Vergence is linearly related to Δz.

$$\text{Vergence} = -\phi^2 \Delta z$$

Badal Optometer - Chief Ray



System is telecentric, meaning magnification is constant.

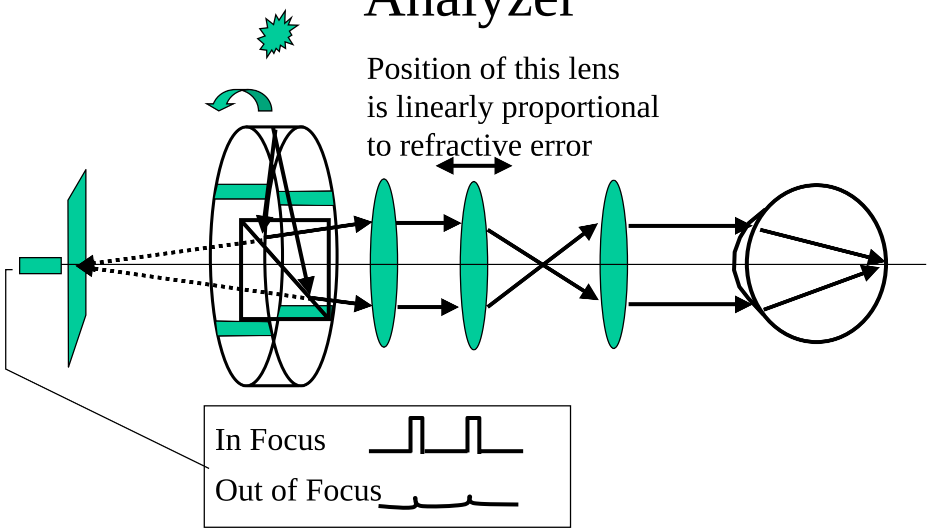
$$\text{Vergence} = -\phi^2 \Delta z$$

Autorefractors

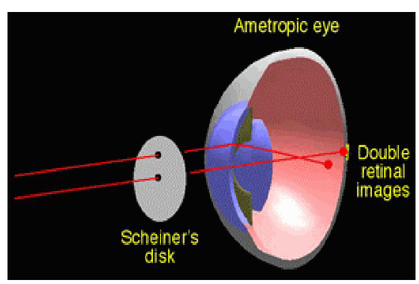
Autorefractors are devices that automatically and objectively measure refractive error in patients.

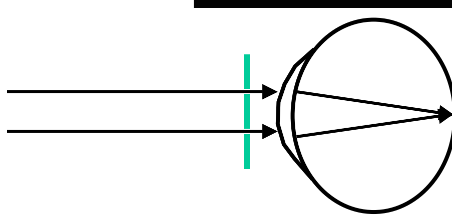
They usually have very repeatable measurements, but tend to be slightly off from a patient's subject refraction. Therefore, they are good for clinical studies to track changes in refraction and as a starting point for a subjective refraction.

Autorefractor – Image Quality Analyzer



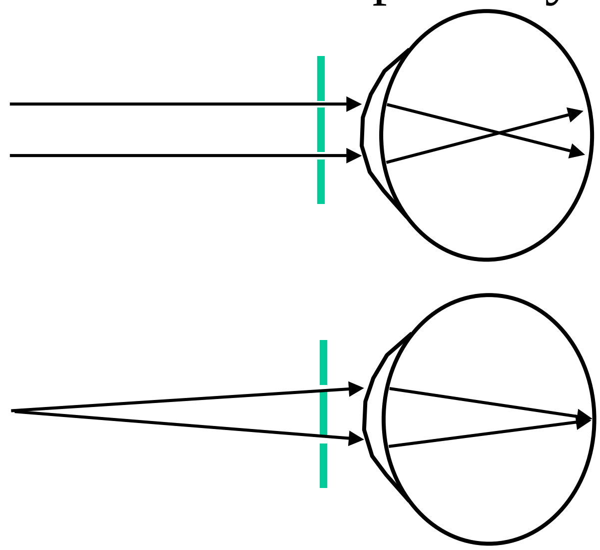
Scheiner Principle - 1619



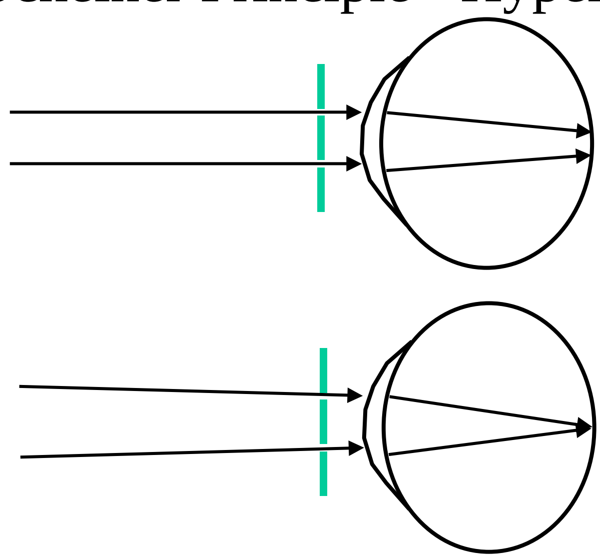


We saw earlier that the Spatially Resolved Refractometer takes advantage of this principle

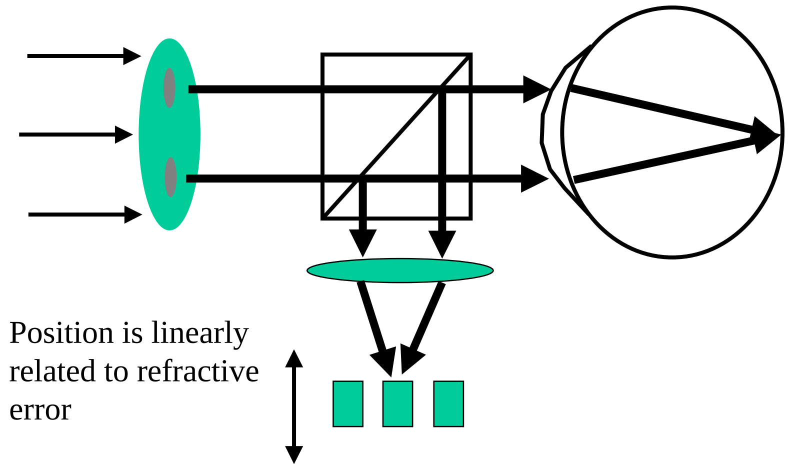
Scheiner Principle - Myopia



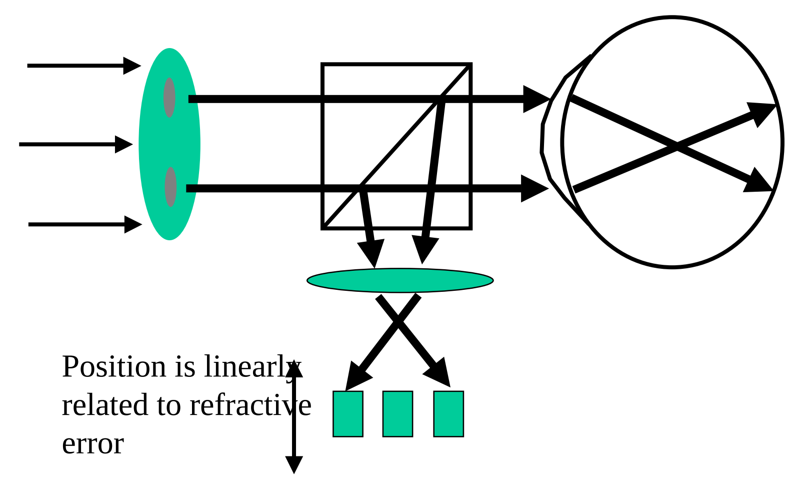
Scheiner Principle - Hyperopia



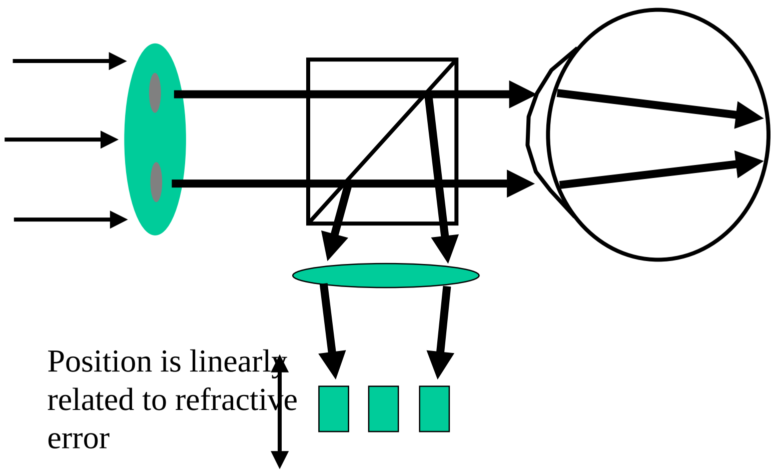
Autorefractor – Scheiner Disk



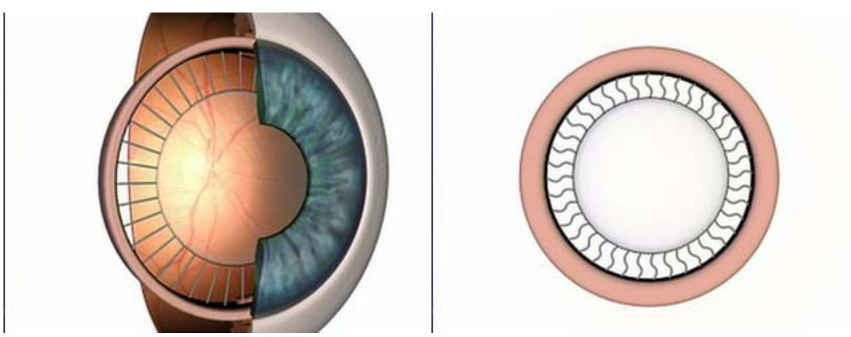
Autorefractor – Scheiner Disk



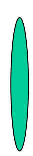
Autorefractor – Scheiner Disk



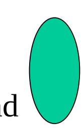
Accommodation



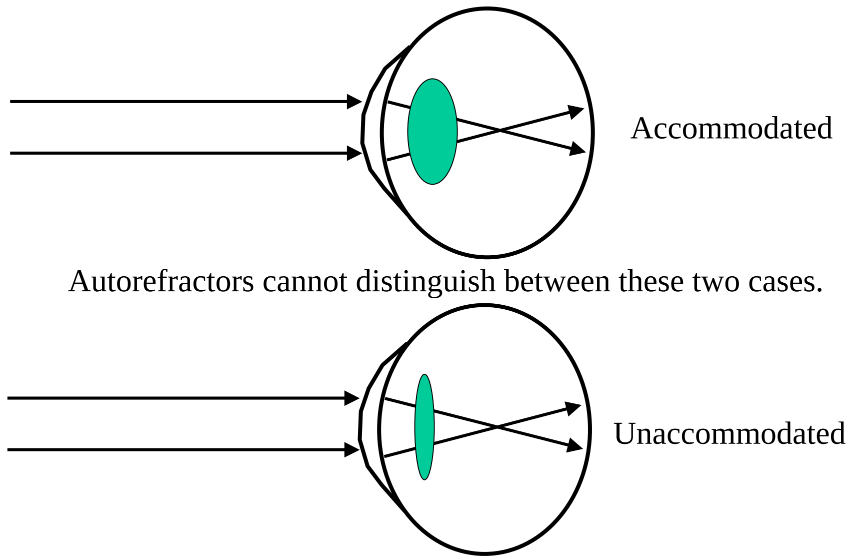
Relaxed ciliary muscle pulls zonules taut an flattens crystalline lens.



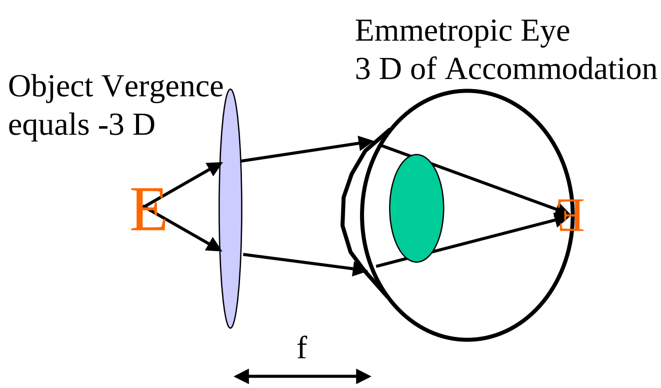
Constrict ciliary muscle releases tension on zonules and crystalline lens bulges.



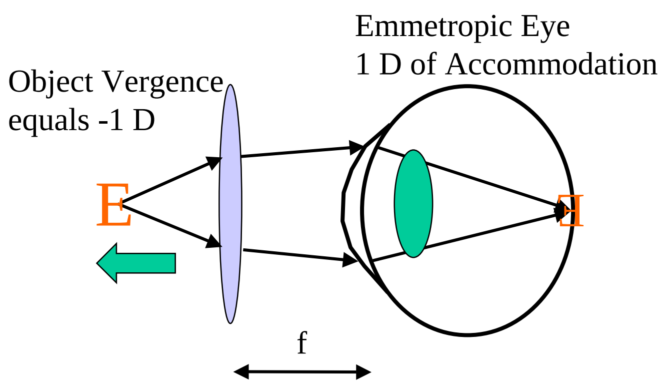
Autorefractor - Issues



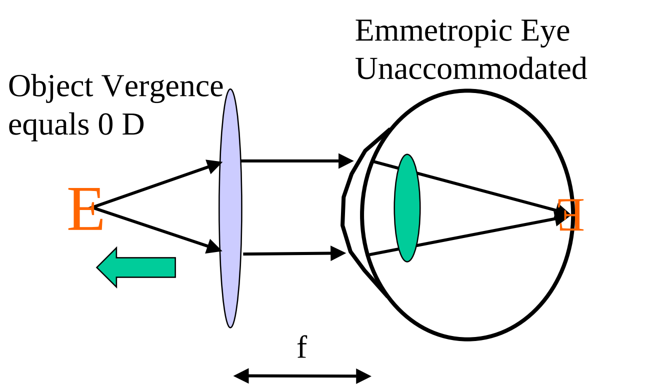
Badal Optometer - Fogging



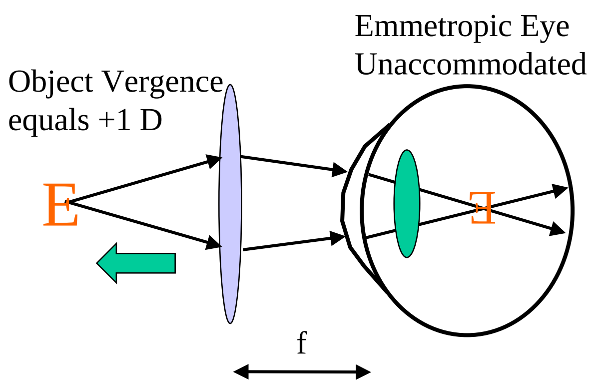
Badal Optometer - Fogging



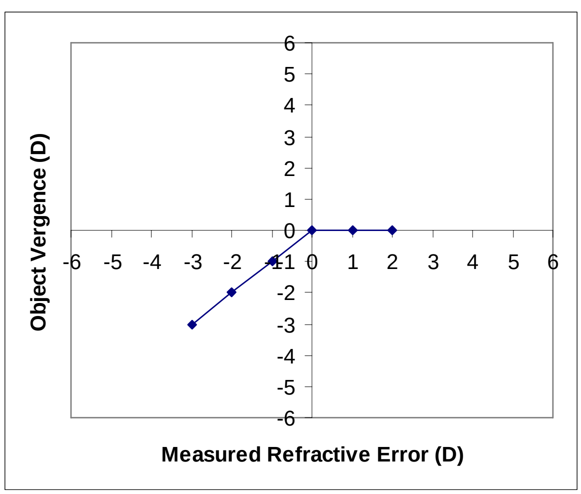
Badal Optometer - Fogging



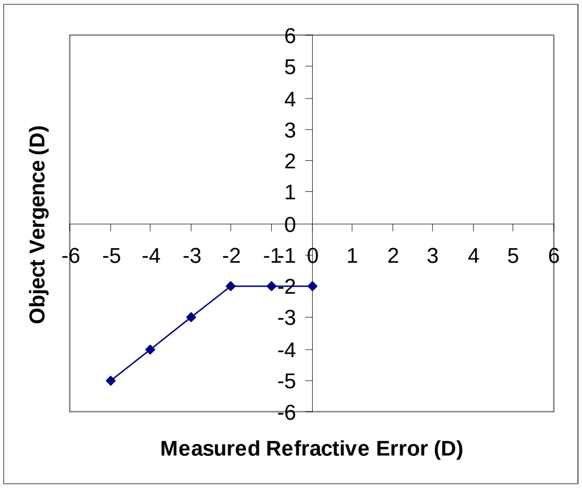
Badal Optometer - Fogging



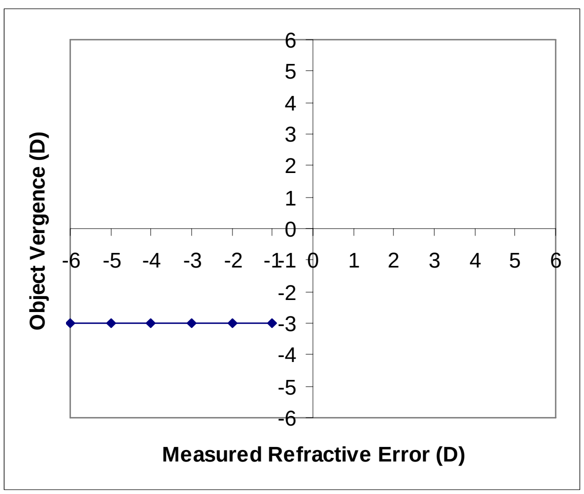
Fogging - Emmetrope



Fogging - 2 Diopter Myope

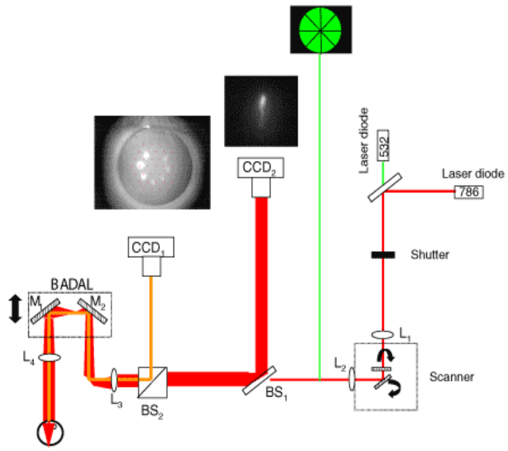


Fogging - 3 Diopter Myope with Presbyopia

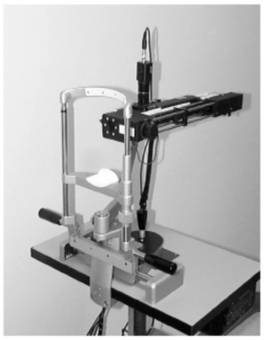


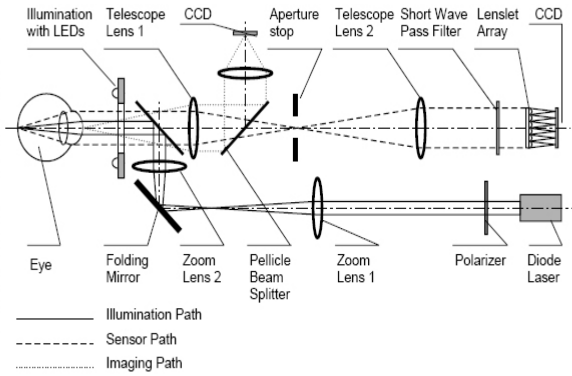
Fogging

Badal Focusing Block

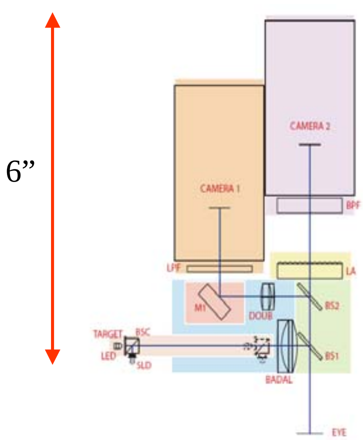


Traditional Shack-Hartmann Sensor





SHAR - Shack Hartmann Autorefractor

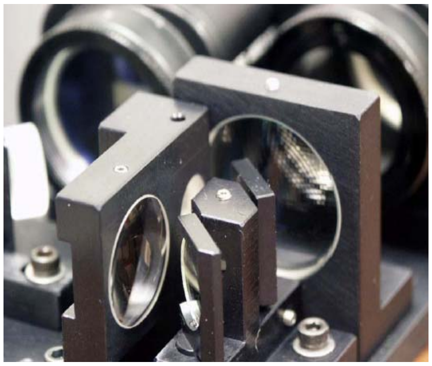


- •Illumination/Fogging Channel
  - SLD source superimposed on fogging target in Badal configuration
- •Alignment Channel
  - provides live video of pupil
- •Measurement Channel
  - displaced Shack Hartmann sensor

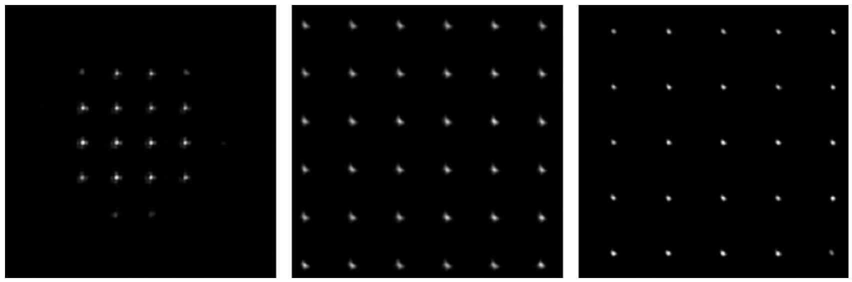
Displaced SH Sensor

- Wavefront no longer measured at pupil plane, but instead at a location in front of the eye.
- Must compensate for this displacement. Similar to vertex adjustment for spectacles and contact lenses.
- Extreme errors will overfill CCD sensor or underfill lenslet array.

SHAR



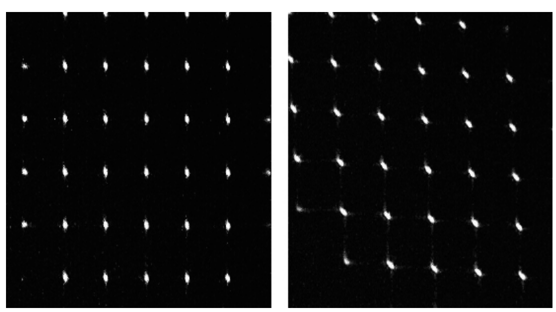
SH Grid Patterns



-5 D | Plano | +5 D

Spots stay uniformly spaced with defocus, but the relative spacing changes.

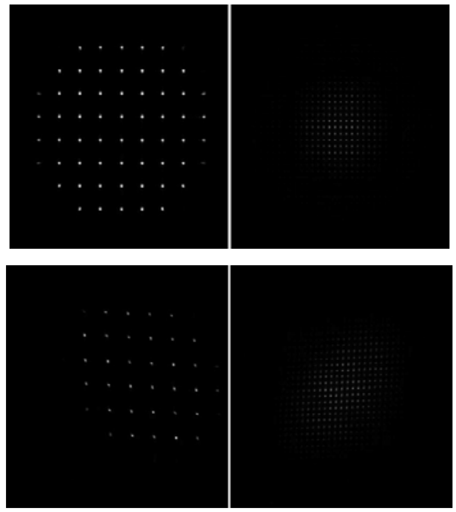
SH Grid Patterns



+5 D cyl x 180° | +5 D cyl @ 45°

Grid becomes rectangular and skews as the cylinder axis is rotated.

Fourier Transforms



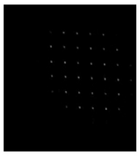
Fourier Transforms

- One spot in Fourier space contains information about all of the spots from CCD space.
- In Fourier space, only two spots need to be analyzed to get sphere, cylinder and axis.
- Noise tends to have a much higher frequency than the spot pattern, so it gets pushed to the edge of the Fourier image. Central peaks are clean.
- Modulus of Fourier transform is independent of decnetration of pupil.

Fourier Transforms

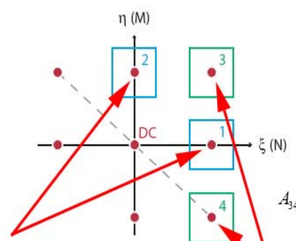
$$W(x,y) = Ax^2 + Bxy + Cy^2$$

$$g(x,y) = \sum_{m,n} \left[\delta\left(x - \{(1-2Af)nx_0 + fBmy_0\}\right) \cdot \delta\left(y - \{(1-2Cf)my_0 + fBnx_0\}\right)\right].$$



$$G(\xi,\eta) = comb\left(\left[1-2Af\right]x_0\xi - fBx_0\eta\right) \cdot comb\left(\left[1-2Cf\right]y_0\eta - fBy_0\xi\right).$$

Fourier Transform Peaks



$$A_{12} = \frac{1}{2f} - \frac{\eta_2}{2fx_0\left(\eta_2\xi_1 - \eta_1\xi_2\right)}$$

$$A_{34} = \frac{1}{2f} + \frac{\eta_3 - \eta_4}{2fx_0\left(\eta_4\xi_3 - \eta_3\xi_4\right)}$$

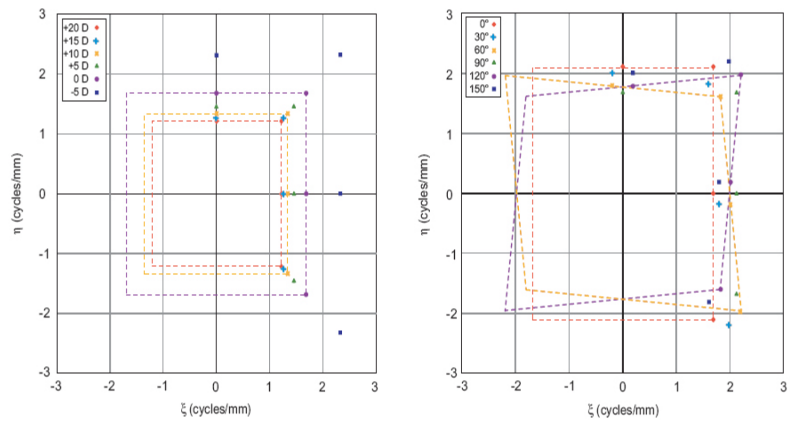
$$B_{12} = \frac{\xi_2}{fx_0\left(\eta_2\xi_1 - \eta_1\xi_2\right)} = \frac{\eta_1}{fy_0\left(\eta_2\xi_1 - \eta_1\xi_2\right)}$$

$$B_{34} = \frac{-\xi_3 + \xi_4}{fx_0\left(\eta_4\xi_3 - \eta_3\xi_4\right)} = \frac{-\eta_3 - \eta_4}{fy_0\left(\eta_4\xi_3 - \eta_3\xi_4\right)}$$

$$C_{12} = \frac{1}{2f} - \frac{\xi_1}{2fy_0\left(\eta_2\xi_1 - \eta_1\xi_2\right)}$$

$$C_{34} = \frac{1}{2f} + \frac{\xi_3 + \xi_4}{2fy_0\left(\eta_4\xi_3 - \eta_3\xi_4\right)}$$

Fourier Transform Peaks



Autorefractor Comparison