Combined Objective and Subjective Optometer

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Aberrometers and Autorefractors use Infrared Light

- Probe beam hits retina
- 0.03% of light scatters out of retina for wavefront measurement
- Conversion is needed from infrared measurement to visible refraction
Two reasons visible refractions differs from infrared reading

1) Chromatic aberration

2) Infrared scatter layer is at a different plane than the photoreceptors

Scatter Layer might be RPE (retinal pigment epithelium), sclera, cone entrances, choroid, inner limiting membrane, outer limiting membrane.
Combined Instrument was built to study location of scatter layer

Step 1. Cycloplege subject’s eye to freeze accommodation

Step 2. COAS measures eye

Step 3. Subject adjusts stage in subjective optometer for “in focus” condition
Subjective optometer uses 840 nm to avoid chromatic aberration

- Chromatic aberration would obscure effect we want to study
- 50 microwatts of 840 nm are clearly visible (lab experiment)
- Safety limit at 840 nm is 770 microwatts for 8 hours a day so it possible to build a safe infrared optometer (ANSI Z136.1-2000)

- Plots from Modern Optical Engineering (Warren J Smith) show eye is sensitive to 840 nm light. (But does decline by factor or ten every 50 nm.)
Options for Subjective Optometer

- **Young’s Optometer**: Subject adjusts stage until target appears to be in best focus
  - Not suitable because 840 nm appears dim. Subjects would be frustrated.

- **Scheiner Disk**: Subject adjusts stage until dots overlap
  - 840 nm bright enough
  - Astigmatism affects power that is measured, complicating data reduction
Laser Speckle Optometer

- Laser Speckle Optometer: Subject adjusts stage until speckle pattern does not move
  - 840 nm bright enough
  - Astigmatism does not affect stage location for stationarity (instead affects apparent direction of speckle motion changes angle)
Laser Speckle is built into Badal Optometer

When stage is set “in focus”, dots appear to “boil.”
When stage is too myopic, dots appear to move to left.
When stage is too hyperopic, dots appear to move to right.

Coherent Point Source

Diffuser Wheel on 26 RPM motor

10° Holographic Diffuser works best for high transmission and large speckles
Combined Instrument
Calibrate Instrument with Model Eye

- **Subjective Optometer**

- CCD simulates retina and it is on a micrometer stage
- Lens simulates cornea and lens

- Step 1: Set CCD to some distance
- Step 2: COAS measure eyes sphere S
- Step 3: Researcher adjust stage to D in optometer for stationary speckle
- Step 4: Plot S versus D for many points. Calculate slope (mm per diopter)
Preliminary Results

• Speckle optometer is creates clearly visible speckles
• Alignment to speckle optometer is sensitive
• Objective and subjective readings are about 0.5 to 1.0 diopter different
• Corresponds to differences of about 0.10 mm to 0.15 mm
• Limited data taken up to now. Better results expected in future
Combining Chromatic and Scatter Layer in Optical Model

- Chromatic Aberration based on Indiana Chromatic Eye
  - single ellipsoidal refracting surface
  - homogenous media

- Add Infrared Scatter Layer located distance $X$ from photoreceptors
Refractive Adjustment Equation

- \( S(\text{vis}) = 1/L - (V(\text{ir}) + 1/(L+X)) \times (n(\text{vis})-1)/(n(\text{ir})-1) \)

- \( S(\text{vis}) \) = Spectacle Refraction
- \( L \) = assumed length on an emmetropic eye (16.666 for 60 D eye)
- \( V(\text{ir}) \) = vergence of infrared light actually measured by aberrometer
- \( X \) = distance between infrared scatter layer and photoreceptors
- \( n(\text{vis}) \) = index of refraction of eye at 555 nm = 1.328020
- \( n(\text{ir}) \) = index of refraction of the eye 840 nm = 1.334278

Effect of Chromatic Aberration Only

- Set $X=0$ in refractive adjustment equation.
- Adjustment has negative value.
- Adjustment is stronger for more myopic eyes.

![Graph showing refractive adjustment due to chromatic aberration only (x=0)](image-url)
Effect of Scatter Layer only

- Use same wavelength of for both n(ir) and n(vis)

- Effect is a constant value in positive direction

![Graph of Refractive Adjustment due to Infrared Scatter Layer Offset only (x=0.125 mm)]
Combine both effects

- Scatter layer and chromatic aberration adjustments offset each other for a total effect of about 0.7 diopters.
- Combined model gives better fit to clinical data than applying 0.7 diopter to all patients.

![Combined Refractive Adjustment due to Chromatic and Infrared Scatter Layer Offset](chart.png)