Quality of Vision

- Visual Acuity only assesses a patient’s visual threshold.
- Light scatter is the predominant factor that determines the quality of vision at the retina.
- Peripheral light sources that cause glare will not impact the foveal image if the media is perfectly clear but if there is light scatter than it will impact the quality of the central image.
Imaging Glare Source

Glaresource

Clear Crystalline Lens
What are the sources of light scatter that humans perceive as glare?

- **Air Medium** – Dust, water droplets (fog), sand, pollution
- **Cornea** – Anterior surface (tear film—lipid disorders, SPK, epithelial irregularity, stromal- edema, haze, endothelium–guttae, scars
- **Aqueous** – Flare (Protein) and Cells
- **Crystalline Lens** – Cataracts
- **Vitreous** – Asteroid Hyalosis and Syneresis Scintillans
Scattered Light Reduces Patient’s Image Quality and Contrast
Scatter Formula

Lord Rayleigh = \( \frac{1}{\lambda^4} \)

- Shorter wavelengths of light scatter more than longer wavelengths
- Purkinje Shift -- explains sensitivity to different lighting conditions
- Photopic vision human perceive light at peak sensitivity of 555 nm
- Mesopic/scotopic peak sensitivity 507 nm
- Human more sensitive to scatter at night due to increased light scattering at 507 nm
Light Scatter

Rayleigh scattering gives the atmosphere its blue color
Veiling Glare from Fog

Intense Light scatter caused by fog and water droplets in the atmosphere
Dirty, scratched, fogged lenses in front of the eye will cause glare and light scatter.
Tear Film/ surface Irregularities

- Lipid layer scatter
- Surface irregularities SPK, striae
- All sources that can highly impact visual quality
- Can lead to dissatisfaction post-refractive surgery
Corneal Structure

- Lattice work of collagen fibers maintain clarity and structure of cornea
- Changes to structure can lead to loss of transparency and increased light scatter
- Corneal edema can have a large impact on refraction and light scatter
Lattice Structure of the cornea must maintain exact organization to maintain organization and visual clarity.
Corneal Transparency

Forward Light Scatter:
- Haze
- Edema
- Inflammation
- Surface irregularity
Imaging Glare Source

Glare Source

Clear Crystalline Lens
Scatter from Cataracts: Causing Glare

- Glare Source
- Cataractous Lens
- Glare Rays
- Image of Glare Source
Effects of Cataract Caused Scatter

- Scattered light reduces contrast of vision
- Reduces the quality of a patient’s vision
- Causes glare that can create disability in the vision and will be worse at night
- Imperfections in the lens will not be picked up by Wavefront analysis
- Scatter will reduce the intensity of perceived light and this is not qualified in a wavefront analysis
- Essential to measure glare and its effect on the point spread function
- Only HD Analyzer can make this analysis
Light Scatter caused by the lens can be quantified and qualified.
WaveFront Versus Scatter

- Wavefront is not reliable in the midst of any opacity that is impacting the visual pathway.
- A Wavefront map will be generated but it will not quantify or assess light scatter.
- HD Analyzer is the only instrument that provides an objective measure of light scatter.
Polynomial surfaces are added together to create a fit for the surface error.
Hartmann-Shack Sensing

CCD-Image -> Lens Array -> Outcoming Wave
WaveFront Resolution Extremely important!

- **Increasing resolution provides ...**
  - Improved spot quality
  - Reduces spot cross over effect
  - Better reconstruction

- **Practice Benefits**
  - Ability to capture more patients
  - Detection and treatment of HOA’s
  - Detection of Tear Film Condition
  - Improved treatment generation

Keratoconus eye with 400μ resolution

Keratoconus eye with 210 μ resolution
Exact Same Wavefront Errors
Data Points are in same place

Significant Light Scatter

Small Light Scatter
Aberrometers measure the wavefront at this location.

OAS evaluates the images on the retina in this situation.
Double pass principle
This parameter is obtained from the relative intensity of the external scattered light area to the area of the central light intensity.

OBJETIVE SCATTER INDEX (OSI)
Analyze and Objectively Quantify Cataracts

Correlation between LOCS and Ocular Scatter Index (OSI)
Intraocular Scattering

Optical Scatter Index (OSI)

<table>
<thead>
<tr>
<th>OSI Range</th>
<th>LOCS III ~</th>
<th>Scattering</th>
<th>Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Increased</td>
<td>Consider intervention</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Abnormal</td>
<td>Classical indication</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.3</td>
<td>5</td>
<td>Abnormal</td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td>6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
COMPARISON OSI – LOCS III

LOCS 1

OSI = 0.4

OSI = 0.6

OSI = 0.8

LOCS 2

OSI = 2.3

OSI = 1.9

OSI = 1.2

LOCS 3

OSI = 3.8

OSI = 6.2

OSI = 3.0

LOCS 4

OSI = 4.4

OSI = 3.9

OSI = 3.8
Optical Quality and Scatter with LASIK

HD Analyzer Study
Pre-op
1 hour Post-op
1 day Post-op

Courtesy: Jack T. Holladay, MD, MSEE, FACS
Clinical Professor of Ophthalmology
Baylor College of Medicine
Houston, Texas, USA
Visual Recovery Post-LASIK

- Visual acuity improves over time
- Quality of vision is reduced due to increased light scatter and contrast
  - Function of edema
  - Surface irregularity
  - Quality of femto ablation
- Visual quality improves during recovery period
Severely reduced contrast has a large effect in the quality of a patient’s vision. This is not reflected in standard acuity measurements.
A large increase in Ocular Scatter; despite correction of patient’s myopia. This has a drastic effect in the quality of a patient’s vision. This is due to edema post-op and surface irregularity caused by surgical trauma.
1 DAY POST-OP

Improved contrast even within 24 hours as the edema resolves as surface recovers.

Pre-OP vs. Post-OP image comparison with quantitative data:
- MTF cut off (c/deg): 38.710
- Strehl ratio: 0.196
- Width at 50% (arc min): 2.51
- Width at 10% (arc min): 8.66
- VA 100%: 1.29
- VA 20%: 1.00
- VA 9%: 0.56

OD Sph.: -1.750  Cyl.: -0.500  Axis: 172

Artificial pupil diameter (mm): 4
Measured pupil diameter (mm): 3.9
Objective spherical refraction (D): 0.500
Selected spherical refraction (D): 1.000
Correction: Acquisition notes:
Total correction

OD Sph.: -1.750  Cyl.: -0.500  Axis: 172

Correction: Acquisition notes:
Total correction 1 day post lasik

1 day post-op, MTF and OQAS values show improved contrast as edema resolves.
Improved Ocular Scatter even within 24 hours of LASIK

PRE-OP

1 DAY POST-OP

2.62 Width at 50% (arc min) 2.83
9.86 Width at 10% (arc min) 9.29

0.6 OSI 0.7

Artificial pupil diameter (mm): 4
Measured pupil diameter (mm): 5.3
Objective spherical refraction (D): 1.250
Selected spherical refraction (D): 1.250
Correction: Acquisition notes: Total correction

OD Sph.: -1.750  Cyl.: -0.500  Axis: 172

OD Sph.: -1.750  Cyl.: -0.500  Axis: 172

Artificial pupil diameter (mm): 4
Measured pupil diameter (mm): 3.9
Objective spherical refraction (D): 0.500
Selected spherical refraction (D): 0.500
Correction: Acquisition notes: Total correction 1 day post lasik