IOP Sensing

STMicroelectronics is working with Swiss company Sensimed to develop a contact lens with nano-sensors fabricated in silicon-based MEMS technology which can be used to measure the shape of the human eye and could be used in the early diagnosis of conditions such as glaucoma.
Slide 4

1.5 mm³ IOP Monitor

- Continuous IOP monitoring
- Wireless communication
- Energy autonomy
- Device components
  - Solar cell
  - Wireless transceiver
  - Chip-to-digital converter
  - Processor and memory
  - Power delivery
  - Thin film Li battery
  - MEMS capacitive sensor
  - Biocompatible housing

Slide 5

Another IOP Sensing Contact Lens

These contact lenses with a pattern of conductive silver wires could be used to measure pressure inside the eye and study glaucoma.

University of California

Slide 6

Contact lenses to detect blood sugar changes

Developed by biochemical engineering professor Jin Zhang at the University of Western Ontario in Hamilton, the new technology benefits from hydrogel contact lenses made from extremely small nano-particles. These nano-particles react with glucose molecules found in tears, causing a change in the color of the lens.
Slide 7

Photochromic contact lenses
- Nano sized tunnels that can fill with dye
- Faster response than photochromic spectacles

Slide 8

Drug dispensing contact lenses
- Ciprofloxacin release via a bandage contact lens
- Month or longer drug delivery for other medications

Slide 9

Microsoft and UW
Microsoft and the University of Washington are developing an electronic contact lens that can non-invasively monitor and wirelessly report blood sugar levels
Researchers at the University of Washington are incorporating micro-circuitry for augmented reality applications. Diffraction is expected to limit the scope of the application.

Virtual and Augmented Reality Contact Lenses

Screen too small for rich content
Pain: Media Bottleneck
Unattractive Styling
Narrow Field of View
Excessive Bulk

Solution: Contact Lens Enabled Wearable Display
Slide 13

Innovega Inc. iOptik™ Contact Lens

- Outer lens: sharpens view of normal surroundings (50% of population need corrective lenses)
- Center lens: streams HD/3D Digital Media from eyewear flat panels or projectors

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VMAX IN PRACTICE

David I. Geffen, OD, FAAO

Slide 15

Refraction
- Over 100 years the same method
- Confusing for the patient
- Inaccurate
- Low Tech
Slide 16

PSF Refraction Is More Sensitive
- Changes in 0.05D are now noticeable

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Vmax
- Ease of use
- Ease of patient understanding
- Extreme Accuracy
- High Tech
Slide 19

Practice Benefits
- High Tech Look and Feel
- Get out of the Dark Ages
- Patients hate “Which is Better, One or Two”
- Greater Reliability

Slide 20

Results

Slide 21

Patient Responses
- Easier to tell the difference
- High tech
- Less strain
- Feels more accurate
Multi-spectral Imaging

- Provides progressive views through the retina from the ILM to the choroid
- Creates a series of monochromatic en face fundus spectral slices for added diagnostic insight

Conventional vs. Multi-Spectral
Spectral Slicing

RHA™: MSI Technology
Spectral slices allow for fundus dissection of the retina

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RHA™: MSI enables a spectral dissection for localization and interpretation of retinal pathologies

<table>
<thead>
<tr>
<th>Monochromatic Light Sources</th>
<th>Examples of Structures Best Viewed with MSI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monochromatic Light</strong></td>
<td><strong>Examples of Structures Best Viewed with MSI</strong></td>
</tr>
<tr>
<td><strong>Superficial Structures Highlighted</strong></td>
<td>Epiretinal membranes, retinal folds, cysts, exudates</td>
</tr>
<tr>
<td><strong>Mid Retinal Structures Highlighted</strong></td>
<td>Retinal vasculature, haemorrhages, intraretinal microvascular abnormalities, drusen, exudates</td>
</tr>
<tr>
<td><strong>Deep Retinal Structures Highlighted</strong></td>
<td>RPE architecture, pigmentary anomalies, macular holes, nevi, melanomas</td>
</tr>
</tbody>
</table>

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PID 79 - Optos

Composite

Slide 30

PID 79 - Optos

Green
Slide 31

PID 79 - Optos

Red

Slide 32

PID 79 - RHA, 662nm

Slide 33

PID 79 - OCT, Macular Hole
To date, 18% of my patients screened on the RHA have had suspect areas of interest to pursue further. This has drastically increased the utility of my OCT and I am now selling 4 times more nutriceuticals. 

Dr. David Geffen
Slide 49

**Tears as an in vitro Diagnostic Platform**

- Tears are an ideal matrix for non-invasive testing
  - Derived from blood
  - Largely acellular
- Tears known to have thousands of proteins & genes
  - Potential for many ophthalmic & non-ophthalmic markers
- Biomarker normalization using osmolarity
  - Fundamentally corrects for tear film instabilities
  - More accurate reporting of proteins, genes, metabolites
  - Combines multiple markers & payments on a single chip

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**Tear Hyperosmolarity: the Central Mechanism Causing Ocular Surface Inflammation, Cell Damage and Symptoms in Dry Eye Disease**

DEWS Report, 2007

Tear hyperosmolarity stimulates a cascade of inflammatory events:
- Inflammatory tear cytokines and MMPs
- Apoptotic cell death
- Reduced and altered tear mucins
- Reduced lubrication
- Up-regulation of HLA-DR expression on surface cells
- Disruption of epithelial junctions
- Intra-epithelial changes in surface cells
- Tracks severity of disease linearly and tracks response to therapy and is tightly linked to tear film instability

Slide 51

**Using Tear Osmolarity in the Diagnosis of Dry Eye Disease**

- If one or both eyes > 308 mOsms/L or larger than a 8 mOsms/L difference between eyes
- Normal subjects have a tight band of variability
- Patients with mild/moderate DED show variability
  - Variability in the variability of this stage in which compensatory mechanisms are still operative in response to environmental stress
  - Variability confirms rather than confounds the DED diagnosis
  - Am J Ophthalmol 2011 May
- Patients with moderate to severe DED have tear osmolarity which varies between eyes and over time but generally remains elevated within the abnormal range
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Osmolarity Disposable Chip

Slide 53

TearLab™ Tear Collection

Slide 54

Historical Diagnostic Tests

- Pt questionnaire
- Schirmer Test
- Tear meniscus height
- Tear break-up
- NaFl
- Lissamine Green or Rose Bengal
- Phenol thread test
- Interferometry (not practical in clinical setting)
Slide 55

Osmolarity in the Diagnosis of Dry Eye Disease

- Osmolarity is the "gold standard" test for Dry Eye Disease
  - 45 years peer reviewed research
  - Osmolarity has been added to definition of Dry Eye
  - Global marker of Dry Eye, indicating a concentrated tear film

Clinical Test

<table>
<thead>
<tr>
<th>Test</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmolarity</td>
<td>87%</td>
</tr>
<tr>
<td>Schirmer</td>
<td>31%</td>
</tr>
<tr>
<td>TBUT</td>
<td>25%</td>
</tr>
<tr>
<td>Staining</td>
<td>31%</td>
</tr>
<tr>
<td>Meniscus Height</td>
<td>33%</td>
</tr>
</tbody>
</table>

Source: DEWS Report, Ocular Surface April 2007 Vol 5 No 2, & Tomlinson A, et. al., IOVS 47(10) 2006

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Diagnose & Classify Patients Quickly


Slide 57

ORA System™: Designed to Optimize Every Cataract Procedure

ORA's all new Optiwave™ technology takes intraoperative wavefront aberrometry to a new level, providing surgeons a higher level of confidence
ORA System™
(Optiwave™ Refractive Analysis)
 Provides intra-operative refractive information
 Attaches to most surgical microscopes for on-demand intraoperative measurements of sphere, cylinder and axis
 Enables real-time surgical course correction
 "Get it right – right on the table"
 Every ORA system connects live to WaveTec servers to capture every procedure and push software upgrades.

ORA System™ Helps Surgeons Optimize Outcomes for ALL Cataract Patients
 IOL power calculations using aphakic refraction
  • Guides IOL selection
  • Post-refractive IOL power calculations
  • Standard monofocal and aspheric IOLs
  • Presbyopic IOLs
  • Toric IOLs (IOL power)
  • Guides toric IOL cases
  • Guides LRI cases
  • Whether done in the phakic, aphakic, and/or pseudophakic mode

Sample ORA Screen Shots
Slide 61
ORA Toric IOL Results
Cumulative Post-op Refractive Cylinder

- 46%
- 68%
- 83%
- 90%

Mean Pre-op Keratometric Cylinder: 1.83 D +/- 0.88 D
Mean Post-op Refractive Cylinder: 0.49 D +/- 0.50 D

Slide 62
Today's Modern Cataract Surgery
Is it really refractive?

Only 50% of cataract patients get within 0.50 D of attempted correction*

* Represents average of published studies with outcomes ranging between 40% and 60%

Slide 63
ORA System™
Enables Refractive Outcomes

While Over 80% of ORA patients get within 0.50 D of attempted correction
What to Expect After Surgery – Day One

The vast majority of patients will be seen by the surgeon at day one, but if not:

- Look for a quiet anterior chamber
- Continue prescribed therapy (e.g., antibiotics, steroids, NSAIDs)
- Check ocular surface

Traditional Cataract Surgery

- Capsulotomy size directly related to Effective Lens Position
- Corneal incisions are manually executed and imprecise
- High level of phaco power can be associated with post-op complications
- Cataract surgery complications are 10x that of LASIK

Common Incidence

- Vision Threatening Incidence
  - Posterior Capsular Opacification: 10-30%
  - Retinal Detachment: 0.6-1.7%
  - Cystoid Macular Edema (transient): 2-10%
  - Cystoid Macular Edema (persistent): 1-2%
  - Vitreous Loss: 1-5%
  - IOL Malposition: 0.3%
  - Corneal Endothelial Cell Loss: 4-10%
  - Need for Corneal Transplant: 0.3%
  - Endopthalmitis: 0.1%

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Femtosecond Lasers

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The VICTUS Platform

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Catalys – engineered for laser cataract surgery

Catalys was designed for laser cataract surgery
- not a modification of existing femtosecond technology
- 50% smaller footprint than competing systems

Every other laser performing cataract surgery was originally designed for something else
The LenSx® Laser

A dynamic platform technology that will:
- Deliver true refractive cataract surgery with the precision of a femtosecond laser
- Establish Laser Refractive Cataract Surgery - a viable new premium category
- Rapidly advance the evolution of true image-guided intraocular surgery
- Advance the development of a more digitized, predictable approach to lens replacement surgery

Laser Refractive Cataract Surgery

Goal is to Improve Every Procedure, Technology and Surgeon

<table>
<thead>
<tr>
<th>Key Step</th>
<th>Current Surgery</th>
<th>Impact</th>
<th>Safety Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corneal Incision</td>
<td>Not Optimized</td>
<td>Induced Cylinder</td>
<td></td>
</tr>
<tr>
<td>Capsulorhexis</td>
<td>Variable, Not Centered</td>
<td>Variable IOL Position &amp; Effective Lens Power</td>
<td></td>
</tr>
<tr>
<td>Lens Fragmentation</td>
<td>Excessive Ultrasound Power</td>
<td>Delayed Visual Recovery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loss of Endothelial Cells, Capsule Rupture</td>
<td></td>
</tr>
</tbody>
</table>

LenSx® Laser Integrated OCT

Image-guided Laser Refractive Cataract Surgery
- Intuitive touch screen Graphic User Interface
- Real-time video imaging for 3D visualization
- True image-guided surgical planning
Slide 73

**Traditional Lens Fragmentation**

- Initial phaco technique divides the nucleus into quadrants (Divide and Conquer)
- Endothelium effects
- Variations on this technique were developed to reduce phaco power
  - Chop, Quick Chop, Stop and Chop, Flip, etc.
- Difficult to perform
- Lens density dependent

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**Laser Fragmentation**

- Mechanism of Action
- Chop Patterns
- Liquefy Patterns

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**Manual Clear Corneal Incisions**

- Wound architecture limited by hand-held instruments, manual incisions
  - Imprecise tunnel length and geometry
- Frequently require stromal hydration to seal
- Can result in cascading intraoperative difficulties
  - Fluid control, anterior chamber maintenance
- Recent literature suggests an increased incidence of post-op infection
- Incisions may be unstable at low IOPs

References:


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**Incision Configurations Single or Multiplane**

- Computerized programming of incision patterns
- Customizable geometry
  - Angle
  - Depth
  - Width

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**LenSx® Laser Corneal Incisions**

- Customized wound architecture and placement
- Self-sealing incisions

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**Arcuate Incisions**

Traditional, Handheld Diamond Knife

- Manually executed by “tracing” corneal marks
- Inconsistent depth control
- Unpredictable effect due to imprecise wound architecture and depth
- No image-guided surgical planning or visualization
LenSx® Laser Arcuate Incisions

Image-guided surgical planning with 3D visualization
- Real time corneal thickness
- Computer programmed incisions
  - % depth
  - Incision length and position
  - 3D visualization of incision placement
- Predictable incision width,
  tunnel length
- Titratable incisions
  - Adjustable during surgical procedure
  - Adjustable post-op at slit lamp

Laser Arcuate Incision
- Square edge
- Uniform depth (no ripples)
- Precise, reproducible
  - Arc shape
  - Arc length
  - Diameter

Ideal Capsulorhexis
- Reproducible size, shape and well-centered

Current Manual Capsulorhexis
<table>
<thead>
<tr>
<th>Technique</th>
<th>Corneal shape</th>
<th>Incision shape</th>
<th>Cell centration</th>
</tr>
</thead>
<tbody>
<tr>
<td>No capsule, IOL overlap</td>
<td>Phimosis</td>
<td>IOL tilt</td>
<td>IOL decentration</td>
</tr>
<tr>
<td>IOL BI</td>
<td>Difficult phaco maneuver</td>
<td>IOL decentration</td>
<td>Edge catches visual axis</td>
</tr>
</tbody>
</table>
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LenSx® Laser Capsulorhexis

• Reproducible, Precise Circular Shape and Diameter Capsulotomy
• Enables Image-Guided Centration of Capsulotomy

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Effective Lens Position (ELPo)

• Assumed value, from empirical data (A constant and surgeon factor)
• A significant source of IOL power error (Norby, 2008)
  key to post surgery refraction (Hill, 2009)
• Size of capsulorhexis effects ELPo (Cekic, 1999)

Slide 84

Patient Expectation

LenSx® Laser technology provides the patient:

- Perceived benefits of a laser procedure
  - Computer controlled precision
  - Procedural predictability
- A comprehensive, advanced technology approach to lens replacement surgery
- A truly premium, value-added surgical experience
Slide 85

Practice Performance

LenSx® Laser technology provides the surgeon:

- Known benefits of femtosecond technology
  - Improved accuracy of all incisions
  - Predictability at every step
- True image-guided intrascleral surgery
  - Opportunity to create optimal wound architecture
  - Precise capsulotomy design for every IOL
- A strong value proposition
  - A message that easily resonates with patients and staff

Slide 86

Standard-Of-Care Technology

Light Adjustable Intraocular Lens (LAL®)
Developed by Calhoun Vision, Inc

- Photosensitive Silicone Material
- Precise, Non-Invasive Post Operative Adjustments
- >2 Diopter Correction for Myopia, Hyperopia, or Astigmatism
- Non-Toxic, Biocompatible
- Foldable

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Why the Light Adjustable Lens?

- Predictable correction of residual refractive error after lens implantation for optimal distance vision
  - Spherical and cylindrical errors up to 2D
- Customized presbyopia solutions for near and intermediate vision
  - Adjustable Monovision
  - Customized Near Add
  - Asphericity Control
Slide 88

**Light Adjustable Lens**

- Foldable 3-piece silicone IOL
- Blue PMMA modified haptics
- 6.0 mm biconvex optic
- Overall length 13.0 mm
- Manufactured in range from 10.0 D to 30.0 D (+17.0 D to +25.0 D in 0.5 D steps)

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**Mechanism of Power Adjustment**

- Photosensitive silicone macromer diffuses to central region & causes swelling
- Increased power

---

Slide 90

**Light Delivery Device Customized Treatment**

- Standard slit-lamp footprint
- Unlimited flexibility for lens modification
- The heart is the digital mirror device (DMD), which allows customized generation of spatial irradiance profiles

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Slide 91

Adjustment profiles:

- Hyperopia
- Astigmatism
- Myopia

Sphere: ± 2.0 D; Cylinder: -2.0 D

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Customized Presbyopia Solutions

- Adjustable Monovision
- Customized Near Add
- Controlled Addition of Asphericity

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Customized Near Add

- +2.1 D Add over 1.8 mm zone
- +3.5 D Add over 2.0 mm zone
- +2.1 D Add over 2.5 mm zone
- +3.2 D Add over 2.5 mm zone

Pre-irradiation interference fringes
Control of Asphericity

Induction of positive or negative spherical aberration to increase depth of focus

CONCLUSION
The Calhoun Vision Light Adjustable Lens
Predictably achieves excellent distance acuity
A variety of options to customize near and intermediate uncorrected acuity

THANK YOU