More Than Just Lasers, the OCT

Dr. Will Smith
Optometrist

What is a Laser?

• An amplifier of Light

Yanoff, Duker. Ophthalmology Text

What is a Laser?

• An amplifier of Light
• Color (monochromatic)
  • Has one wavelength, therefore one color
• Collimated
  • Parallel rays of light
• Coherent
  • Constant relative phase (in step)

• Red light
• Green light
Essentially an Ultrasound
- A scan that takes up to 70,000 scans/sec
- Resolution of 3 to 6 μm within tissues

What is an OCT?

OCT vs. standard imaging

Penetration depth (log)

Resolution (log)

1 μm
10 μm
100 μm
1 mm
1 cm
10 cm

Confocal microscopy
Ultrasound
OCT

Types

Time Domain (TD)
- First OCT, Poor resolution (400 scans/sec)

Spectral Domain (SD)
- Newest, High resolution (up to 70,000 scans/sec)
Ocular Indications

- Unexplained loss of vision
- Macular holes
- Pseudoholes
- Epiretinal membranes
- Vitreo-macular traction
- Retinoschisis
- Retinal detachment
- Diabetic retinopathy
- ARMD
- Other Retinal lesions

OCT ocular applications

- RNFL thickness
- Optic Disc parameters
- Anterior chamber area, volume and iris thickness
- Corneal thickness
- Rigid contact lens assessment

Retinal Anatomy

- Choroid
  - 10 layers of the retina
  - RPE
  - Photoreception
  - External limiting membrane (ELM)
  - Outer nuclear layer
  - Outer plexiform layer
  - Inner nuclear layer
  - Inner plexiform layer
  - Ganglion cell layer
  - Nerve fiber layer
  - Internal limiting membrane (ILM)
- Vitreous

Retinal Lesions

- Superficial
  - Epiretinal and vitreal membranes
  - Exudates and hemorrhages and cotton wool spots
- Intraretinal
  - Hemorrhages, hard exudates (lipoproteins)
  - Retinal fibrosis and disciform degenerative scars
- Deep
  - Drusen, Retinal pigment epithelial hyperplasia, neovascular membranes, scarring
  - Trauma or laser treatment; Hyperpigmented choroidal nevi
  - Low reflectivity atrophic RPE, Cystoid areas of serous fluid, cystoid edema, Serous neural RD and RPE detachment

OCT ocular applications

- Retina
- Anterior Chamber
- Glaucoma

Optic Nerve Head (ONH) Anatomy
Optic Nerve Head (ONH) Anatomy

Cross-sectional scan of the ONH.

OHN Anatomy

Retinal Nerve Fiber Layer scan of the ONH.

ONH Anomalies

- Myopic peri-papillary atrophy
- Glaucomatous peri-papillary atrophy
- ONH Drusen
- ONH swelling
- ONH Pit
- Coloboma

ONH Anomalies

- ONH Pit Example
OCT ocular applications

- Retina
- Glaucoma
- Anterior Chamber

Anterior Segment Anatomy

- Cross-sectional images of the cornea and anterior segment
- Noncontact, noninvasive technique that provides higher image resolution compared to UBM (Ultrasonic biomicroscopy)
UBM has unique advantage of enabling visualization of structures posterior to the iris such as the ciliary body, zonules and the peripheral lens.

<table>
<thead>
<tr>
<th>AS-OCT vs UBM</th>
<th>Anterior Segment OCT Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator</td>
<td>Anterior chamber depth (ACD)</td>
</tr>
<tr>
<td>Indicator</td>
<td>Anterior chamber angles</td>
</tr>
<tr>
<td>Indicator</td>
<td>Anterior chamber diameter</td>
</tr>
<tr>
<td>Indicator</td>
<td>Pachymetry (limbus to limbus)</td>
</tr>
</tbody>
</table>

UBM table:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>AS-OCT</th>
<th>UBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Optical</td>
<td>Ultrasound</td>
</tr>
<tr>
<td>Resolution</td>
<td>10 µm</td>
<td>5 µm</td>
</tr>
<tr>
<td>Longest scan dimensions</td>
<td>5 X 5 mm</td>
<td>5 X 5 mm</td>
</tr>
<tr>
<td>Contrast enhancement</td>
<td>No</td>
<td>Ultrasound probe does not contact these directly but results in increased depth</td>
</tr>
<tr>
<td>Real-time imaging</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Imaging posterior to iris</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Quantitative measurement</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
**Needed Features**

- Ease of use
- Good laser tracking
  - 1 laser vs 2 lasers
- Good Progression Analysis
- Ability to customize image capture

**Models**

- Zeiss
  - Cirrus HD-OCT 5000
  - Cirrus HD-OCT 500
  - IOLMaster 700*
- Topcon
  - 3D OCT-1 Maestro
  - 3D OCT-2000
  - Spectralis SD-OCT
- Optovue
  - Avanti
  - iScan
  - iVue
- NIDEK
  - Retina Scan Duo
  - RS-3000 Advance 2

**Models**

- Zeiss
  - Cirrus HD-OCT 5000
  - Cirrus HD-OCT 500
  - IOLMaster 700*
- Topcon
  - 3D OCT-1 Maestro
  - 3D OCT-2000
  - Spectralis SD-OCT
- Optovue
  - Avanti
  - iScan
  - iVue
- NIDEK
  - Retina Scan Duo
  - RS-3000 Advance 2

**Cirrus HD-OCT 5000**

- Fully automated (alignment, focus, capture)
- FastTrac tracking
- 4mm field
- Trend Analysis (RNFL, GCC)
- Guided Progression Analysis
- Scans:
  - Retina, ONH, Anterior Segment
  - Angio compatible
FastTrac Technology

Models

- Zeiss
  - Cirrus HD-OCT 5000
  - Cirrus HD-OCT 500
  - IOLMaster 700*
- Topcon
  - 3D OCT-1 Maestro
  - 3D OCT-2000
- Spectralis 3D-OCT
- Optovue
  - Avanti
  - iScan
  - iVue
- NIDEK
  - Retina Scan Duo
  - RS-3000 Advance 2

Topcon 3D OCT

- Full automation (alignment, focus, capture)
- Fundus photo capability and Red-free
- Wide field (up to 8mm)
- Trend analysis (RNFL, GCC)
- Scans
  - Glc and macular report in one scan
  - 3D macula and drusen analysis
  - 3D disc report with RNFL trend analysis
  - Corneal thickness and curvature and angle measurement
Topcon 3D OCT

Models

- Zeiss
  - Cirrus HD-OCT 5000
  - Cirrus HD-OCT 500
  - IOLMaster 700*
- Topcon
  - 3D OCT-1 Maestro
  - 3D OCT-2000
  - Spectralis SD-OCT
- Optovue
- Avanti
- iScan
- iVue
- NIDEK
  - Retina Scan Duo
  - RS-3000 Advance 2

Heidelberg Spectralis SD-OCT

- IR fundus with confocal scanning laser ophthalmoscope
- Fundus photos: IR, blue laser FAF, Red=Free, FA, ICG angiography @ 30x30 (opt 55 deg)
- Scans
  - Macula: detail, fast, progressive analysis
  - ONH: Posterior pole, RNFL with progressive analysis
  - No Ant Seg imaging on standard model

TruTracking Technology

Fig. 2: Image without 🔄 and with active eye tracking 🔄. The red dot indicates the OCT scan, the blue dot indicates the IR laser.
Auto Rescan

- Allow clinician to track changes over time.
- Using the fundus image like a fingerprint, SPECTRALIS automatically places follow-up scans in precisely the same location as the initial scan.

Spectralis Imaging Capabilities

Multi-modality Imaging

Optovue
- Avanti
- iVue

NIDEK
- Retina Scan Duo
- RS-3000 Advance 2

Zeiss
- Cirrus HD-OCT 5000
- Cirrus HD-OCT 5000*
- IOLMaster 700*

Topcon
- 3D OCT-1 Maestro
- 3D OCT-2000

Spectralis SD-OCT

Cirrus HD-OCT 5000

Cirrus HD-OCT 500

IOLMaster 700*

Topcon
- 3D OCT-1 Maestro
- 3D OCT-2000

Spectralis SD-OCT

Wide field scans (up to 8mm)
- Trend Analysis (ONH, GCC, pachy)
- Wellness exam
- Retinal and GCC thickness and Focal Loss Volume
- Scans:
  - ONH: Combined RNFL and GCL report, ONH structure analysis
  - Macula: Retinal trend, GCC
  - Cornea: Pach, Power, Angle measurement
  - angio capabilities
6/4/2019

Models

- Zeiss
  - Cirrus HD-OCT 5000
  - Cirrus HD-OCT 500
  - IOLMaster 700*
- Topcon
  - 3D OCT-1 Maestro
  - 3D OCT-2000
  - Spectralis SD-OCT

- Optovue
- Avanti
- iScan
- iVue
- NIDEK
  - Retina Scan Duo
  - RS-3000 Advance 2

NIDEK RS-3000 Advance 2

- Automated: uses Eye Tracer SLO to obtain image
- Wide field scans (up to 9mm)
- Trend Analysis (RNFL, GCC)
- Fundus perimetry imaging
- Scans:
  - Combined RNFL, GCC, and macula in one scan
  - Anterior chamber/cornea imaging (optional)
- Angio compatibility

NIDEK Retina Scan Duo

- Automated
- Wide field scans (up to 9mm)
- Trend Analysis (RNFL, GCC)
- Color Fundus and Fundus autofluorescence (FAP) imaging
- Scans:
  - Combined RNFL, GCC, and macula in one scan
  - Stereo Disc and Retinal Panorama photos
  - Anterior chamber imaging (optional)
OCT Analysis

- RNFL Thickness
- Macular Thickness
- Ganglion Cell Complex
- Pachymetry

RNFL thickness analysis

Cirrus (RNFL)

Integrated Image with deviation map

Color-coded averages compared to normative data.

Neuro-retinal rim thickness and TSNIT RNFL thickness in line graph

Pie graphs illustrating RNFL thickness averages by quadrant and clock hour
Topcon (RNFL)  Image Quality (Reliability)  Thickness map  Integrated Image with deviation map  Averages compared to normative data.

Pie graphs illustrating RNFL thickness averages by quadrant and clock hour

Spectralis (RNFL)  Image Quality (Reliability)  Thickness map  Asymmetry graph

Pie graphs illustrating RNFL thickness averages by quadrant (normative data)

Optovue (RNFL)  Image Quality (Reliability)  Color-coated averages compared to normative data.

GCC Thickness Map

GCC color-coated avg compared to normative data

Surgical RNFL

New “Hood” Glaucoma Report
NIDEK (RNFL)

- Thickness map
- Pie chart graph of normative data
- Color coated averages map compared to normative data
- Neuro-retinal rim thickness and TSNIT RNFL thickness in line graph

Macular thickness analysis

Pie chart graph of normative data

Neuro-retinal rim thickness and TSNIT RNFL thickness in line graph

Cirrus (Macula)

- Infrared fundus image with color-coded topographical overlay that allows for normative data comparison
- EDTRS grid with thickness measurements displayed in each macular sector
- Vertical tomogram
- Horizontal tomogram

Spectralis (Macula)

- Horizontal line scan overlying infrared fundus image
- Corresponding macular thickness B-scan
Ganglion Cell Complex thickness analysis

Cirrus (GCC)
- Thickness map of the GCL-IPL CD/OVS, overlaying an infrared fundus image
- GCL-IPL thickness averages for each sector
- Horizontal B-scans through the foveal pit indicating good scan alignment
- Deviation maps overlaying magnified images of the macula color-coded compared to normative data.

Table of values for average and minimal thickness

Optovue (Pachymetry)
- Color-coded Thickness map of the cornea
- Normal eye - Pachymetry Map
- Kwarcivoski eye - Pachymetry Map

Anterior Segment Analysis
Optovue (Angle)

- Angle Analysis
- High-resolution images of the vitreous face, angle to anterior chamber, trabecular meshwork, and Schlemm’s canal. Quantiﬁcation measurement tracks enable repeatable measurement of the angle in glaucoma patients.

Progression Analysis

Spectralis (Macula)

- Infra-red thickness map of the macula
- Corresponding B-scan through macula
- Inter-visit changes in retinal thickness.

Spectralis (RNFL)

- RNFL thickness map of individual visits
- Inter-visit changes in RNFL thickness.
Optovue (GCC)

OCT Limitations

- ONH anatomy and ambiguous optic neuropathy findings
- i.e. Myopic Discs
- Shorter eyes may falsely represent higher RNFL values due to camera magnification
- ONH diameters > 4.0mm can falsely affect accuracy of RNFL analysis.
- Inter-visit tolerance limit of about 4um
- Can adjust focus for very myopic eyes (up to -24.00 Dia on Spectralis)

What do the numbers mean?

- OCT has documented RNFL thickness 75 microns as a threshold value, below which, there is a reduction in visual function. This observation has been confirmed with automated perimetry testing
- Mean central foveal thickness: 227um

Imaging Tips

Clinical Pearl: Segmentation Line Terms

When used for OCT analysis, OCT automatically determines the anterior and posterior boundaries of the retinal pigment epithelium (RPE) and the neural retina on the cross-sectional view. Occasionally, the OCT erroneously demarcates the anterior and posterior boundaries of the RPE, resulting in inaccurate measurements. Therefore, any boundary happens with poor scan quality, disruption of the structural integrity of the retina, or if there is a prominent vitreous cavity. Dark voxels or segmentation line among the abnormal findings are not always reflected in the final, analytic report.

Spectral OCT (I/M): scan shows a segmentation line error (blue arrow) at the inferior temporal quadrant (yellow arrow) in interpretation of the images by the posterior segment face. In this case, the anterior temporal retinal thickness is measured as anterior back (green arrow). The segmentation line error that the OCT software to within normal limits.

https://www.reviewofoptometry.com/content/d/tech/technology/c/19985/
**Macula Image quality/Alignment**

- Want quality to be at least Q20

**Poor quality image**

**Enhanced Depth Imaging (EDI)**

EDI is an imaging modality for enhanced visualization of deeper tissue structures in OCT images.

The following structures can be examined:
- The outer retinal layers
- The choroid
- The lamina cribrosa

EDI is available for all OCT scan patterns.

**Future**

- OCT A
- Swept Source OCT (SS-OCT)
ultra-high resolution, three-dimensional images that are displayed as individual layers of retinal vasculature, allowing you to isolate specific areas of interest and see microvasculature that is not easily seen with Fluorescein angiography (FA) or Indocyanine Green Angiography (ICGA).

Perform OCT when refractive lenses do not improve reduced vision.

OCT imaging aids in examination efficiency and helps drive correct diagnosis.

Ocular disease may be detected sooner and managed much more effectively with OCT.
THANK YOU

LET'S GET IN TOUCH
CONTACT ME

Will Smith, OD
awqwadoc@gmail.com