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NOVEL APPLICATIONS OF LEADING-EDGE OCT IN THE DIAGNOSIS AND TREATMENT OF GLAUCOMA

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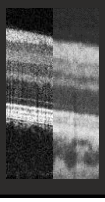
Advantages of going to visible

Higher Axial resolution

- Visible light OCT has an axial resolution ~1-1.4 microns in tissue (~2 um in eye)
- Near infrared OCT axial resolution ~ 5 microns

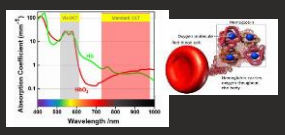
Visible light OCT



Heidelberg Spectralis

Retinal oximetry

- Visible light OCT accesses 10x higher hemoglobin absorption coefficients compared to near-infrared
- Oxygenated and deoxygenated hemoglobin have more distinct spectral features in visible compared to near-infrared



Pi et al. *Biomedical Optics Express* (2018)

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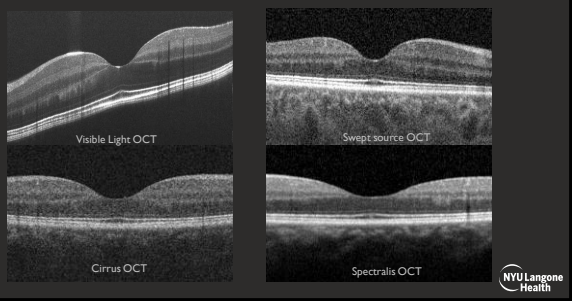
Visible light OCT compared to other technologies



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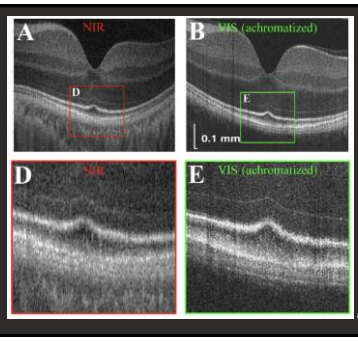
Near IR v. Vis-OCT

Chong SP, Zhang T, Kho A, Bernucci MT, Dubra A, Srinivasan VJ. Ultrahigh resolution retinal imaging by visible light OCT with longitudinal achromatization. BIOMEDICAL OPTICS EXPRESS, 2018. 9(4):1477-1491. https://doi.org/10.1364/BOE.9.001477



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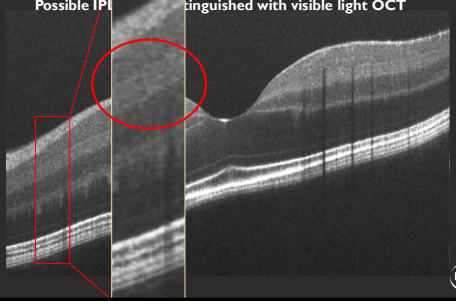
Possible IPL [illegible] tinguished with visible light OCT



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Retinal Oximetry with Visible Light OCT

- **Blood Oxygen Saturation Rate (SO_2):**

$$\frac{C_{HbO_2}}{C_{Hb} + C_{HbO_2}}$$

- SO_2 as a biomarker to monitor retinal metabolism and provide a valuable early indicator of ocular disease
- A visible-light source is necessary for measuring sO2 with spectroscopic OCT
  - Absorption Coefficient of Hb is higher than that in the NIR spectral range, achieving more reliable intensity values for SO2 measurement
  - The shapes of the absorption spectra of Hb and Hbo2 are more distinctive.

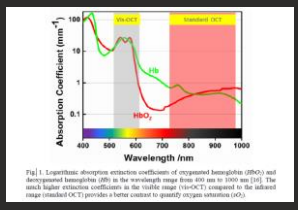

Fig. 1. Logarithmic absorption extinction coefficients of oxygenated hemoglobin (HbO_2) and deoxygenated hemoglobin (Hb) in the wavelength range from 400 nm to 1000 nm [10]. The much higher extinction coefficients in the visible range (vis-OCT) compared to the infrared range (standard OCT) provides a better contrast to quantify oxygen saturation (sO_2).

[SHAOHUA,2018]

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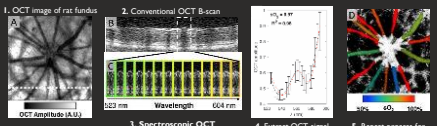
Principle of retinal oximetry with vis-OCT



3. Spectroscopic OCT processing:
Generate multiple OCT B-scans of same location with different wavelength bands

4. Extract OCT signal from blood or vessel wall.
Fit to known values of hemoglobin absorption

5. Repeat process for all blood vessels

Nesper & Soetikno et al. *Vision Research* (2017)

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Scanning pattern

- Vis-OCT scans were obtained using two scanning modes:
  - For each eye of a heathy volunteer, one pair of retinal major artery and vein in superior and inferior regions near the optic nerve head was scanned in raster mode with our prototype vis-OCT (8192 A-scans over 1mm^2, sampling interval = 0.12 μm).
  - Each eye of a healthy volunteer was scanned in circular mode with our prototype (12288 A-scans, circle size 3.37, #Bscans=16)

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Method

- Spectroscopic analysis was done on the raster or circular scans using short-time Fourier Transform (STFT).
- For reliable sO_2 estimation, wavelength-dependent OCT amplitude from the same depth location across multiple A-lines were averaged.

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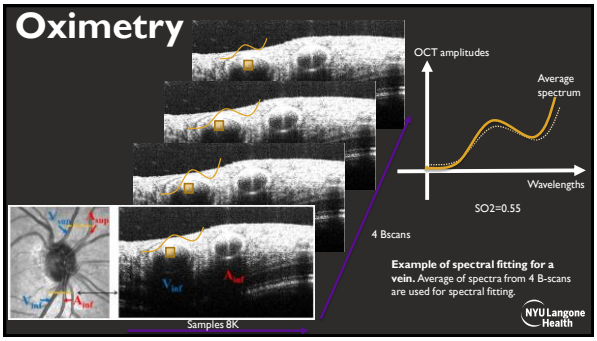
Oximetry



Example of spectral fitting for a vein. Average of spectra from 4 B-scans are used for spectral fitting.

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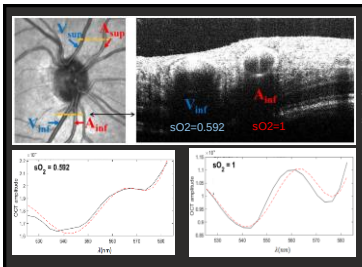

Sampling locations of retinal oximetry. A pair of artery (A) and vein (V) in superior(sup) and inferior(inf) regions near the optic nerve head are sampled (8192 A-scans over 1mm², sampling interval = 0.12 μm) to measure sO_2 in raster mode(highlighted dashed lines).

An example of spectral fitting for a pair of vein and artery in inferior region of Retina

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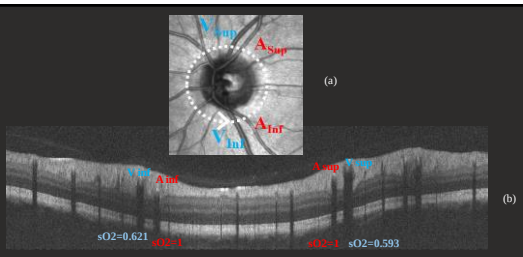

Circumpapillary scans of retinal oximetry. (a) A white dashed circle which indicates the approximate path of the circumpapillary scan on a healthy subject retina. Ainf, Asup and Vinf and Vsup identify arteries and veins in inferior and superior regions, which are sampled to measure sO_2 in circular mode (12288 A-scans, circle size 3.37, #Bscans=16).

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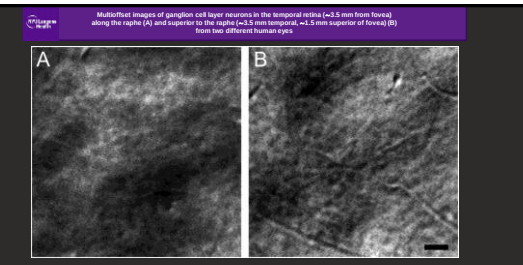

Ethan A. Rossi et al. PNAS 2017;114:3:586-591

PNAS

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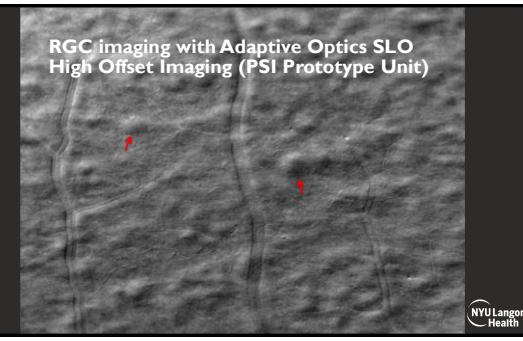

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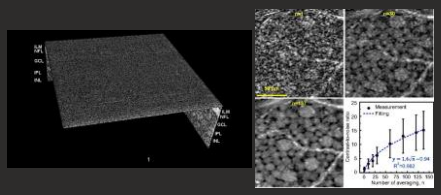
AO-OCT images of GCL somas



Zhuolin Liu et al. PNAS 2017;114:48:12803-12808

PNAS

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Conclusions

- Retinal oximetry is possible with vis-OCT
- Improved layer segmentation with vis-OCT
- Ganglion cells can be visualized with AO-OCT
  - Revolutionary opportunity to characterize cellular changes in glaucoma in the cells damaged by the disease
- Advances offer the potential to identify disease and progression or response to treatment by structural and other than structural means

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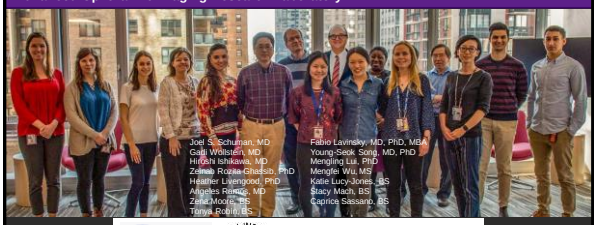

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National Eye Institute
National Institutes of Health
Supported by
Research to Prevent Blindness

NIH Grants: R01-EY025011, R01-EY013178, R01-EY023966, R01-EY022928, R01-EY011289, P30-EY008098, T32-EY017271
Research to Prevent Blindness (New York, NY)

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