ECSE 527 Design Project: MEMs-Based OCT Endoscope

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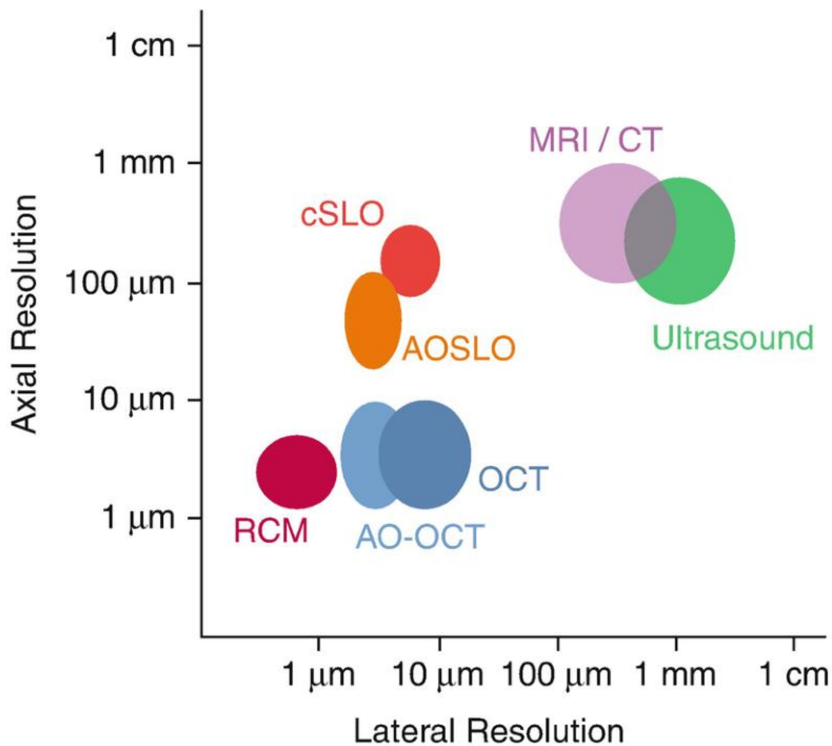
Background

- **O**ptical **C**oherence **T**omography
- Non-invasive and used for *in-vivo* imaging
- Typically uses light from infrared range

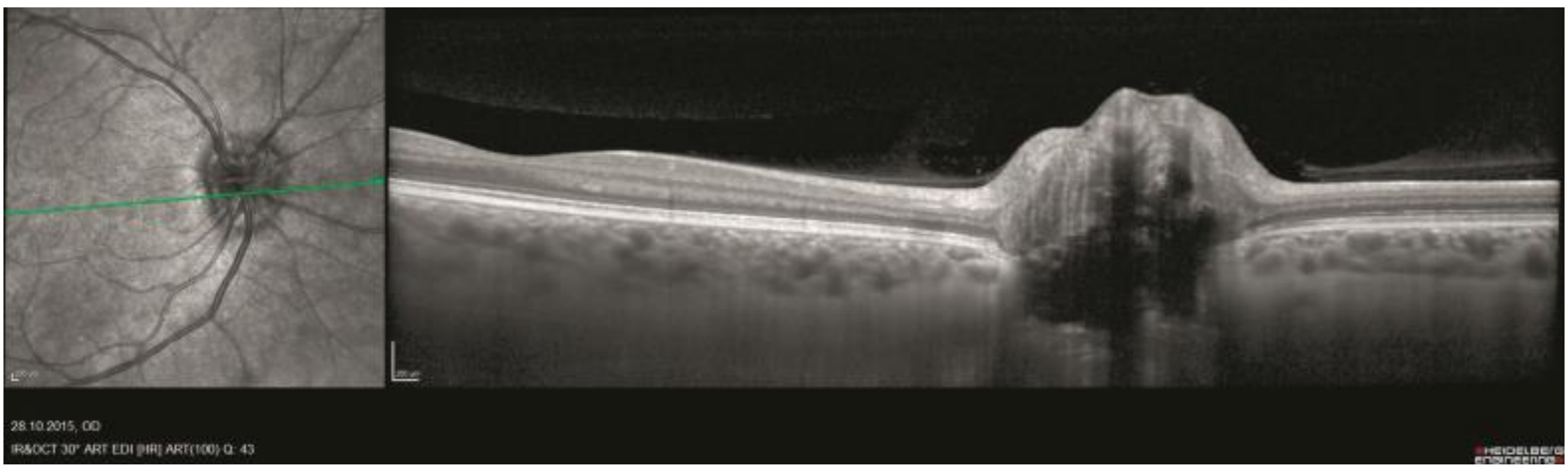


OCT Challenges

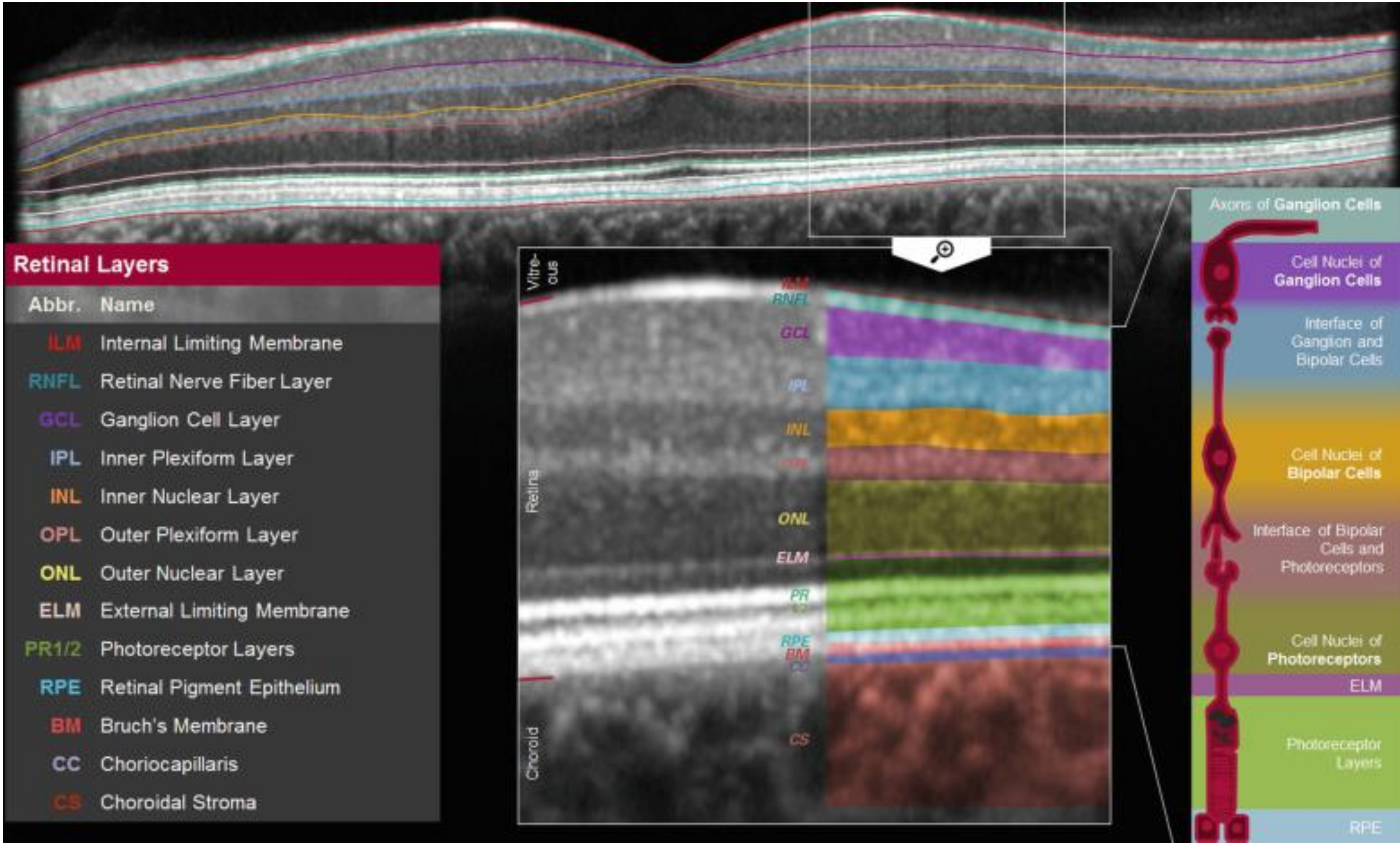
- Very small image size
- Difficult to image larger organs
- Typically small scan angles
  - 10-20°
- Short working distances

Functionality

- Used to produce cross-sectional images of bodily tissue
- Can produce 2D or 3D images
- Laser is scanned along a sample
- Detector receives light reflected from sample
  - Different tissue types reflect different intensities

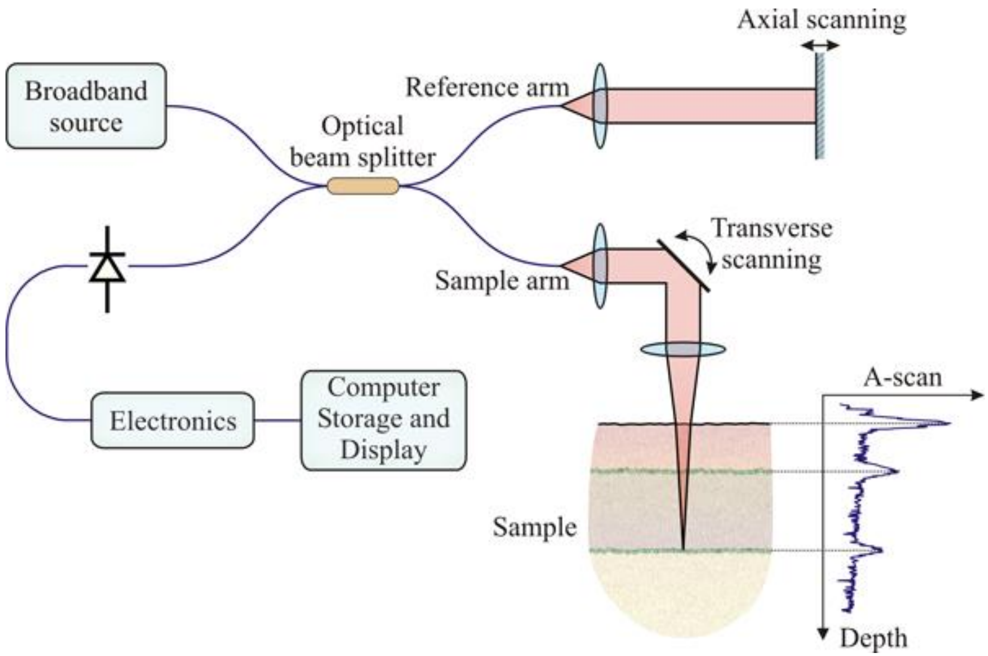


Example OCT Image and Analysis



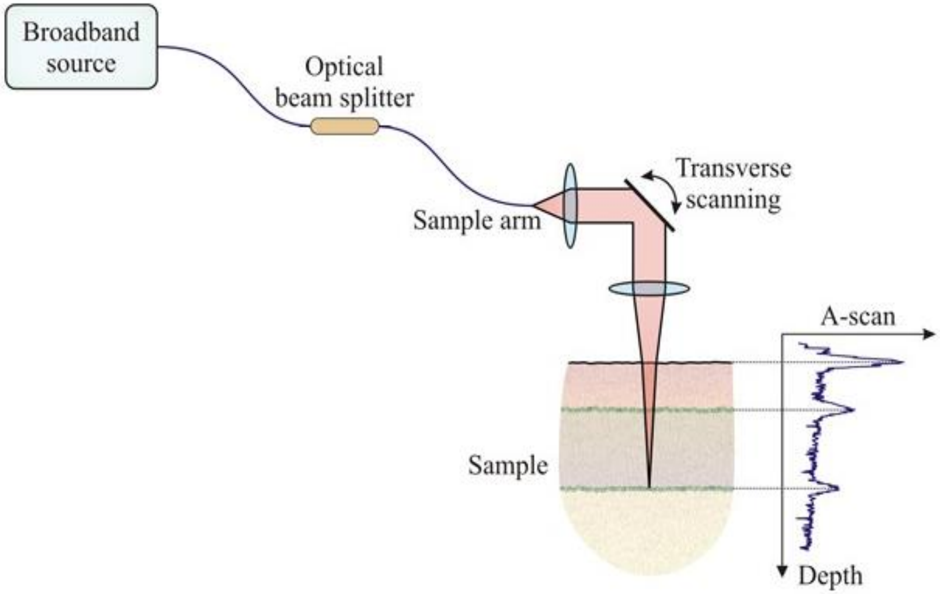
OCT System Overview

- Input beam split into sample and reference
  - Light coming back from both arms is recombined
- Detector reads reflection intensity
- Back-reflection from reference and sample arms interfere and gets converted into an image



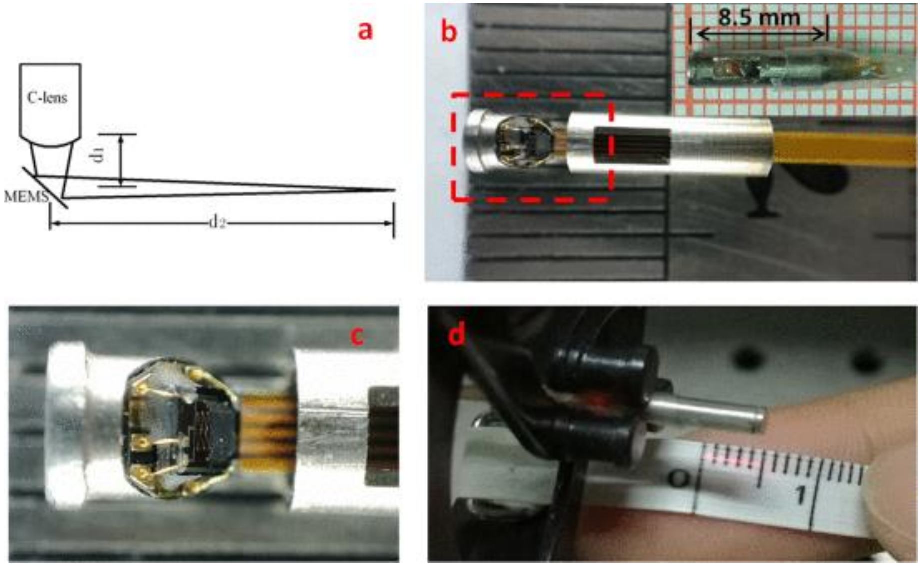
Design Specifications

- Use an 830 nm light source
- Achieve a 5x5 mm^2 field of view
- Fit everything in a tube with a 7 mm diameter
- Only design the beam delivery system



Design Components and Tradeoffs

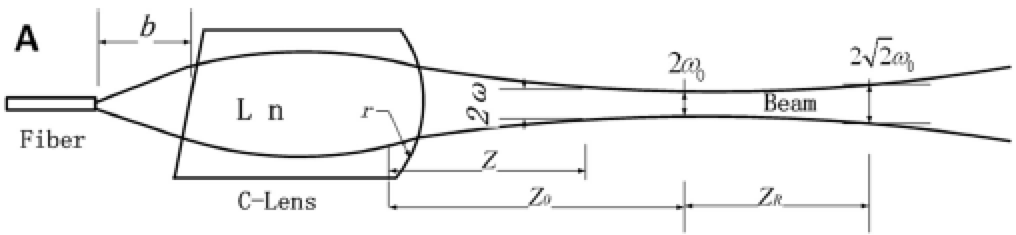
- Used a C-Lens rather than GRIN
  - Focal length was longer than using GRIN Lenses, but occupied much less space
- Followed design from figure to the right
- Mirror angled at 45˚ and tilts ±10° relative to X-plane
- Mirror tilts ±10° relative to Y-plane
- Tube diameter 7 mm

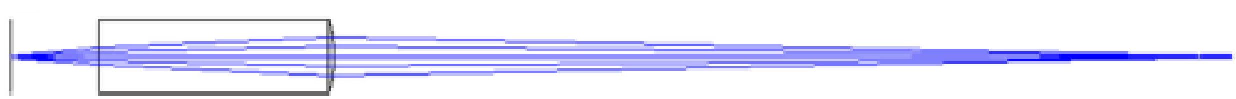


S. Luo *et al.*, "A Miniature Endoscopic Optical Coherence Tomography Probe Based on C-Lens," in *IEEE Photonics Journal*, vol. 10, no. 5, pp. 1-10, Oct. 2018, Art no. 3901310, doi: 10.1109/JPHOT.2018.2870690.

C-Lens Details

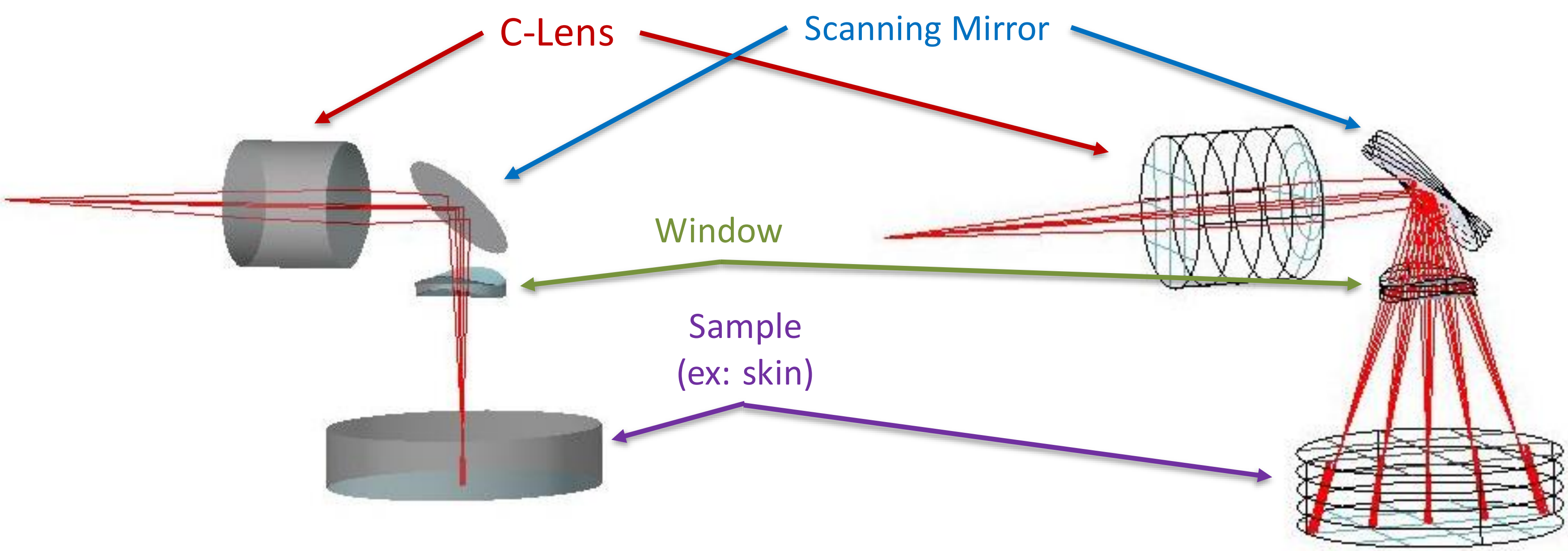
- 5 mm length
- 5 mm radius on curved side
- 1.78 refractive index (SF11 SCHOTT)
- α angle 0 °
- Collimates and focuses light source





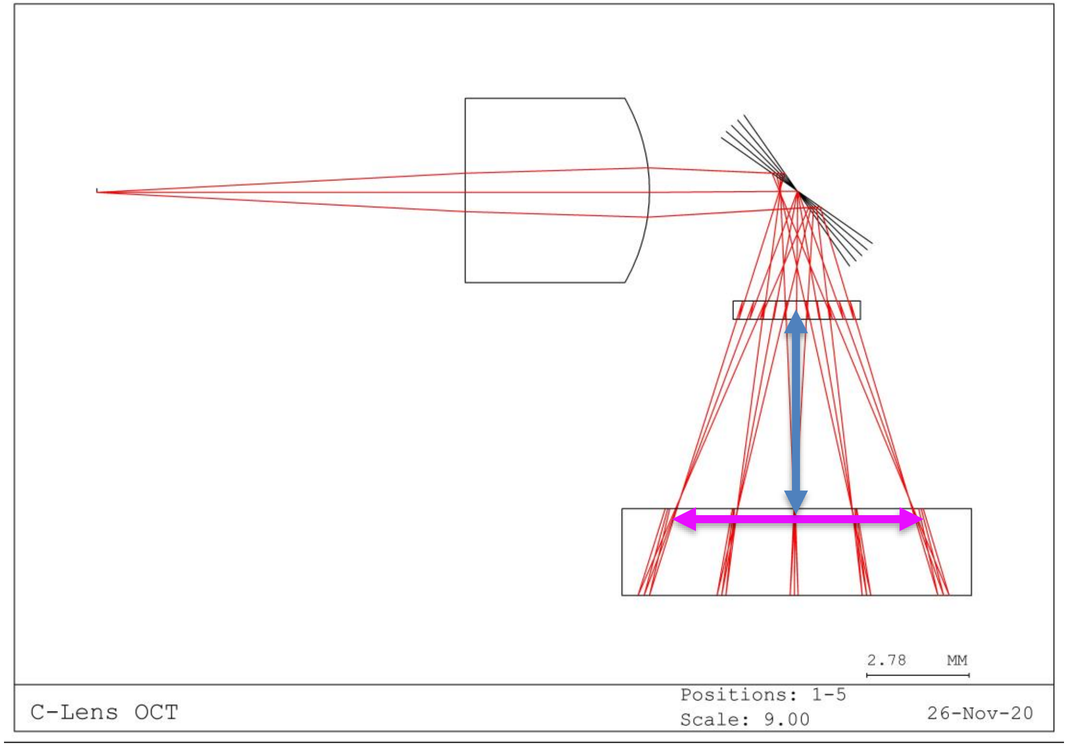
Design Overview

- Beam (830 nm) is sent through a C-Lens
- Mirror reflects beam through a window, onto the sample



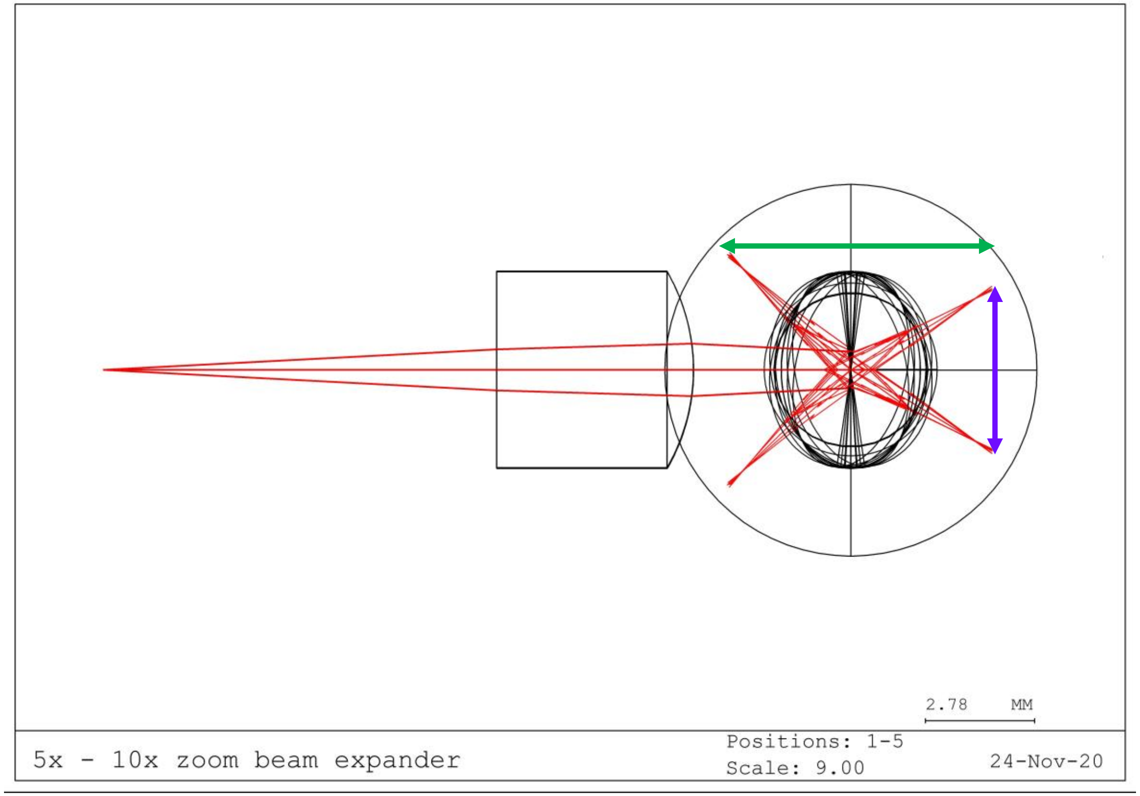
Performance

- Side view of the system with 5 different mirror positions
- Maximum scan Length in this direction is approximately 6.4 mm
- Scan length in the opposite direction is ~ 4.15 mm
- Working distance ~5.15 mm



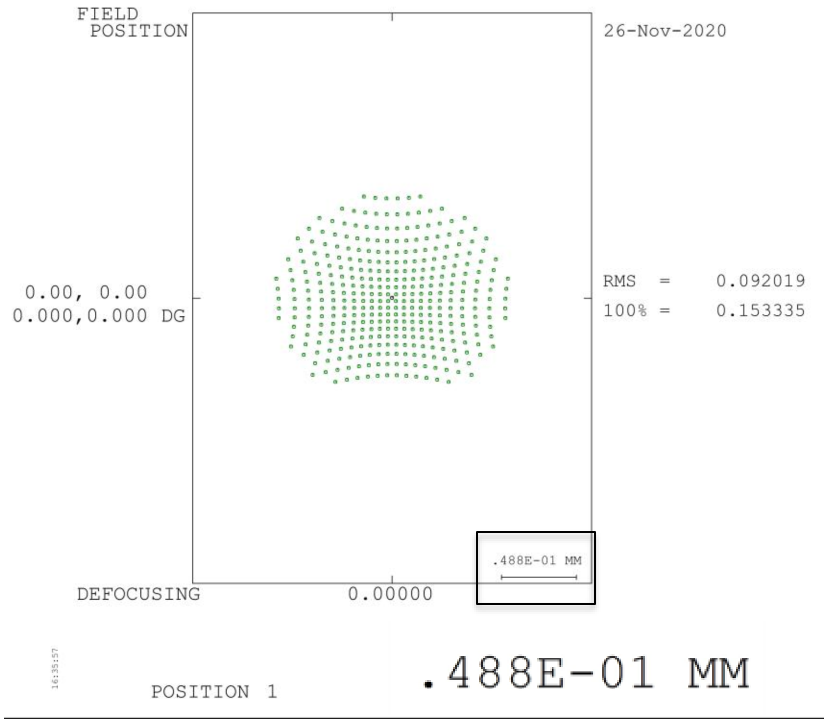
Performance (cont.)

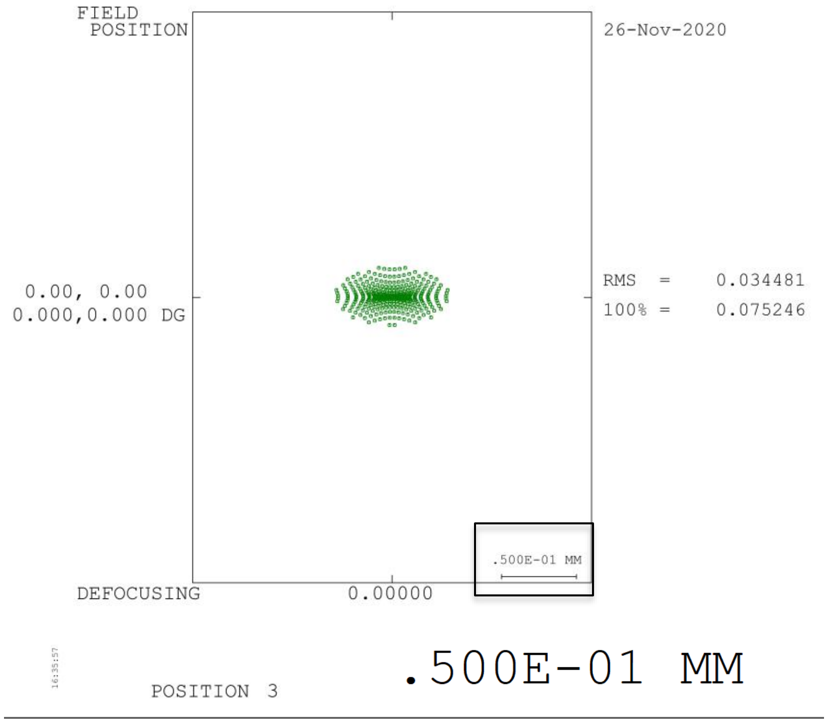
- Resulting field of view
- ~6.4 mm
- ~4.15 mm
  - Larger scan angle would be required for an increase



Spot Size Performance

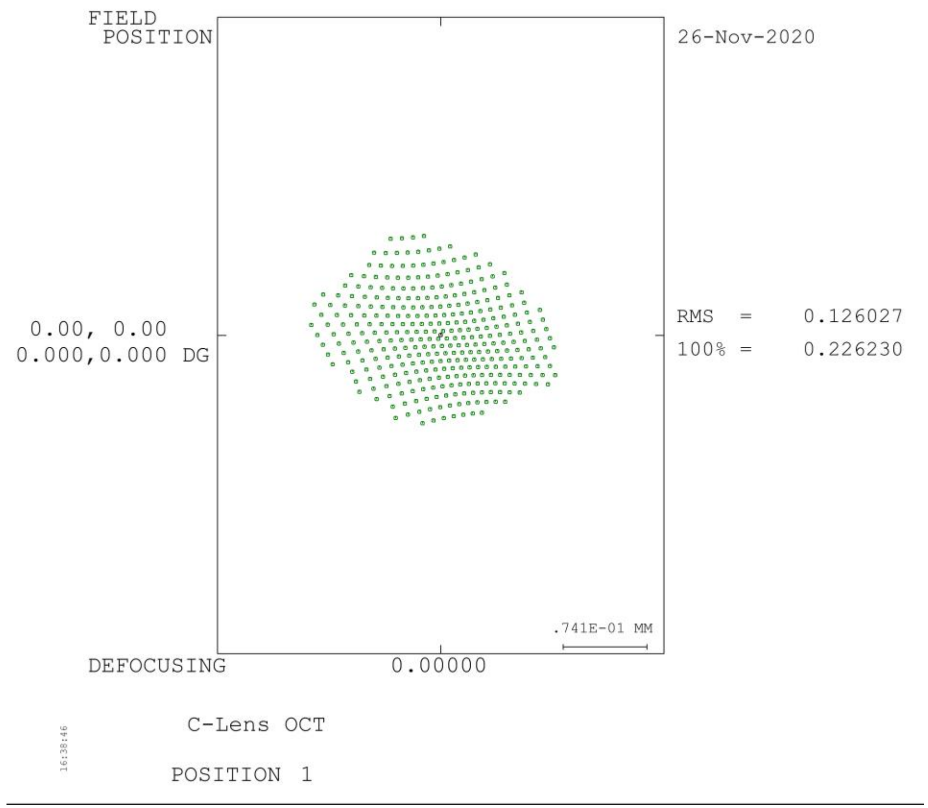
- Spot diagram to the right is the spot size with the best resolution (45° tilt)
- Spot diagram to the left is at 35° tilt
- Low RMS values and small spot size

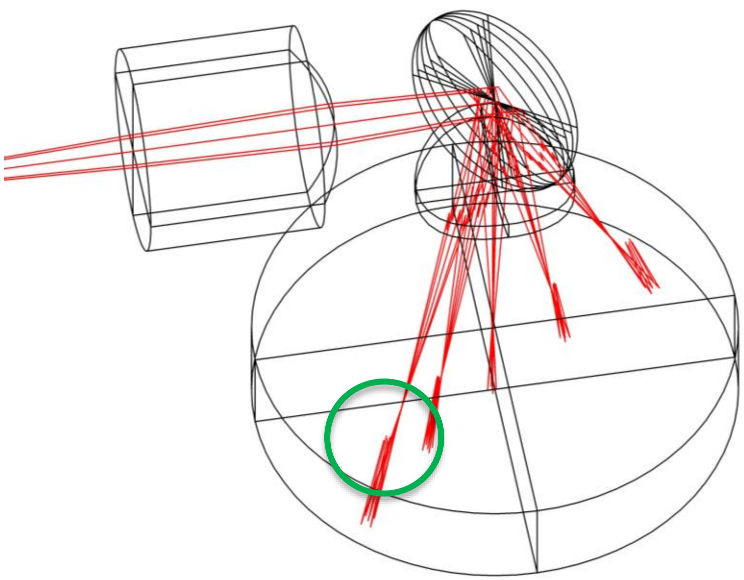




Spot Size Performance (cont.)

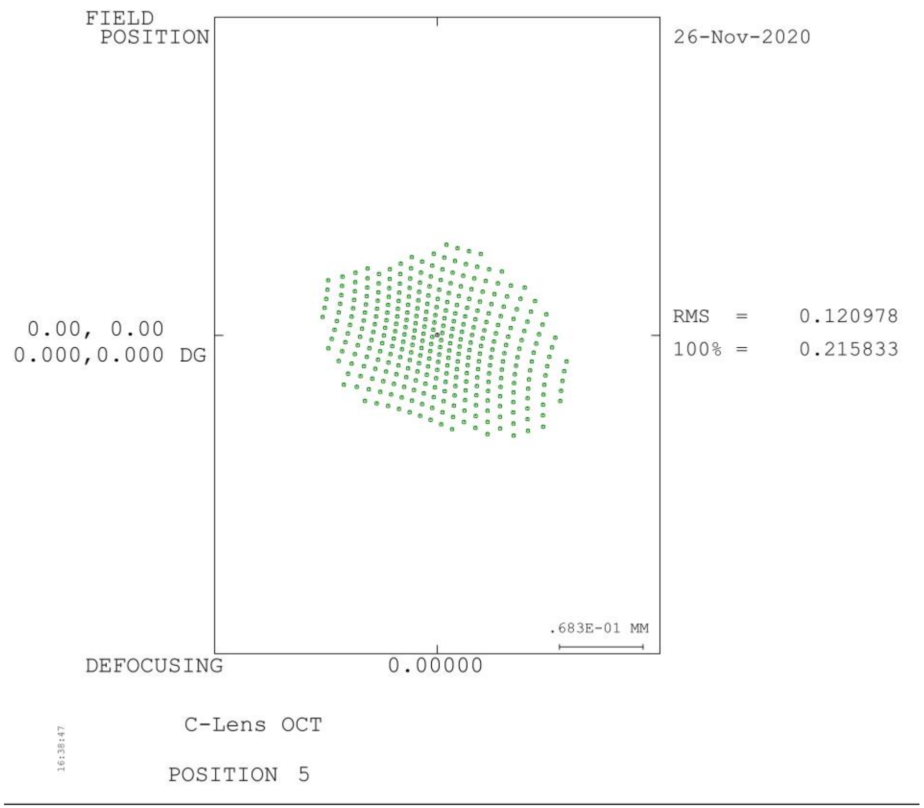
- Spot size with Beta angle tilt included
- Left: Alpha 35°, Beta -10°

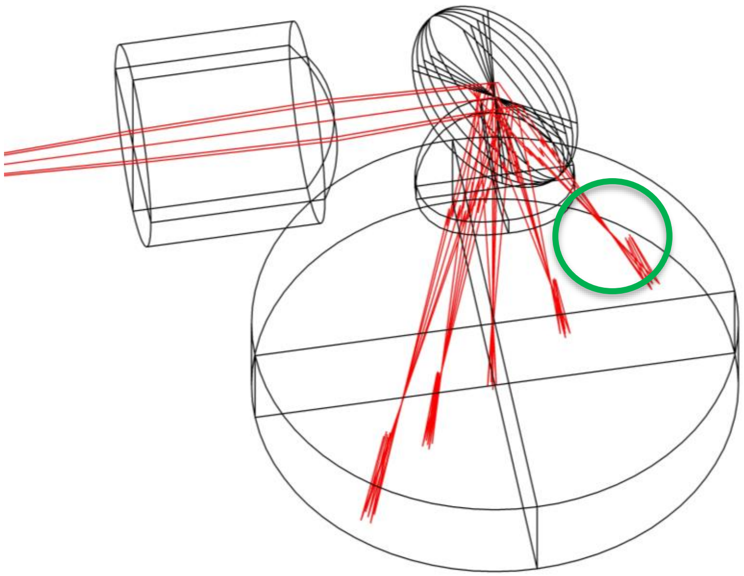




Spot Size Performance (cont.)

- Spot size with Beta angle tilt included
- Left: Alpha 55°, Beta 10°





Future Improvements

- Increase of Beta scan angle to achieve 5 mm length
- Improve transverse resolution
- Fix decreasing resolution as scan moves away from the center angle

References

- Aumann S., Donner S., Fischer J., Müller F. (2019) Optical Coherence Tomography (OCT): Principle and Technical Realization. In: Bille J. (eds) High Resolution Imaging in Microscopy and Ophthalmology. Springer, Cham. https://doi.org/10.1007/978-3-030-16638-0_3
- “Introduction to OCT.” *OBEL*, University of Western Australia, obel.ee.uwa.edu.au/research/fundamentals/introduction-oct/.
- Popescu, D. P., Choo-Smith, L. P., Flueraru, C., Mao, Y., Chang, S., Disano, J., Sherif, S., & Sowa, M. G. (2011). Optical coherence tomography: fundamental principles, instrumental designs and biomedical applications. *Biophysical reviews*, *3*(3), 155. https://doi.org/10.1007/s12551-011-0054-7
- S. Luo *et al*., "A Miniature Endoscopic Optical Coherence Tomography Probe Based on C-Lens," in *IEEE Photonics Journal*, vol. 10, no. 5, pp. 1-10, Oct. 2018, Art no. 3901310, doi: 10.1109/JPHOT.2018.2870690.