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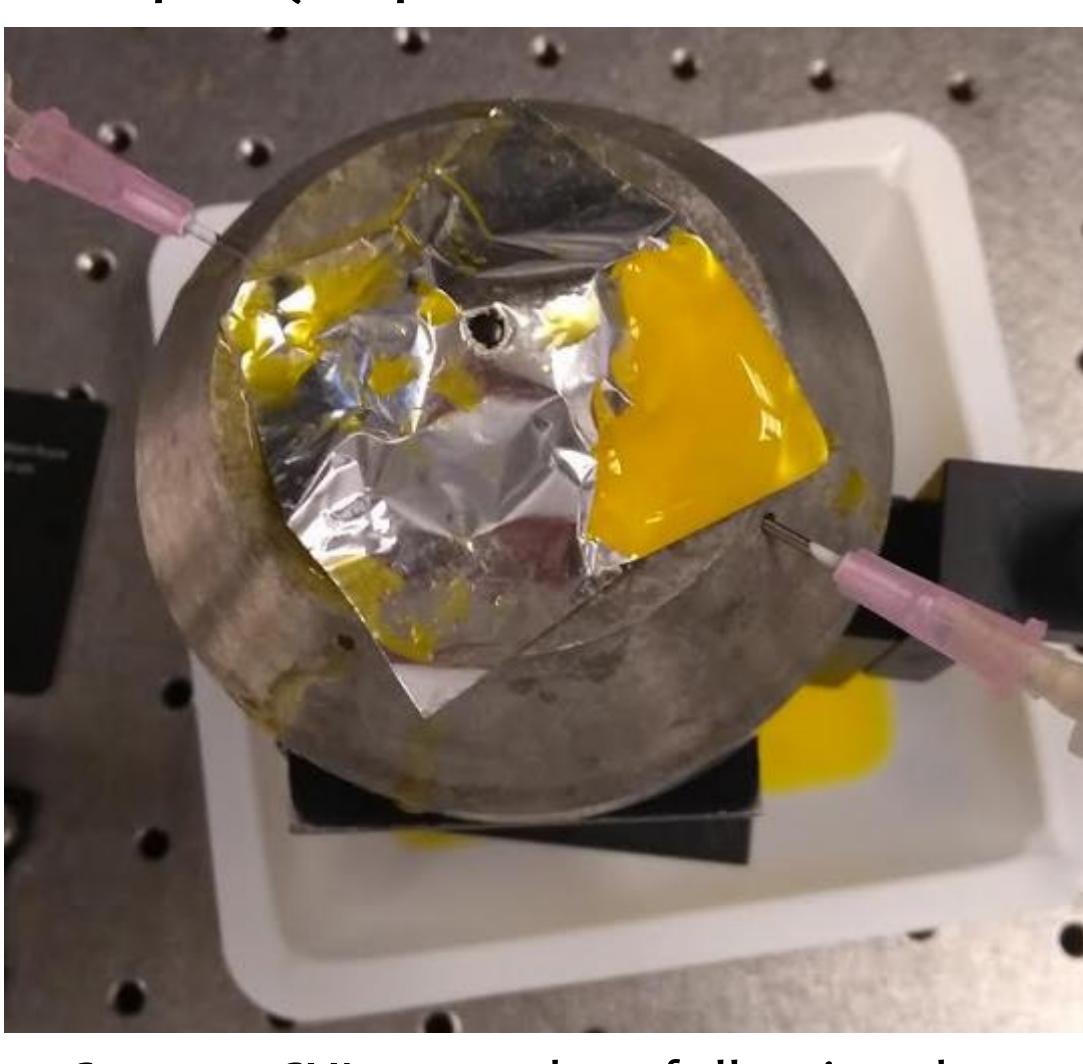
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## Introduction & Background

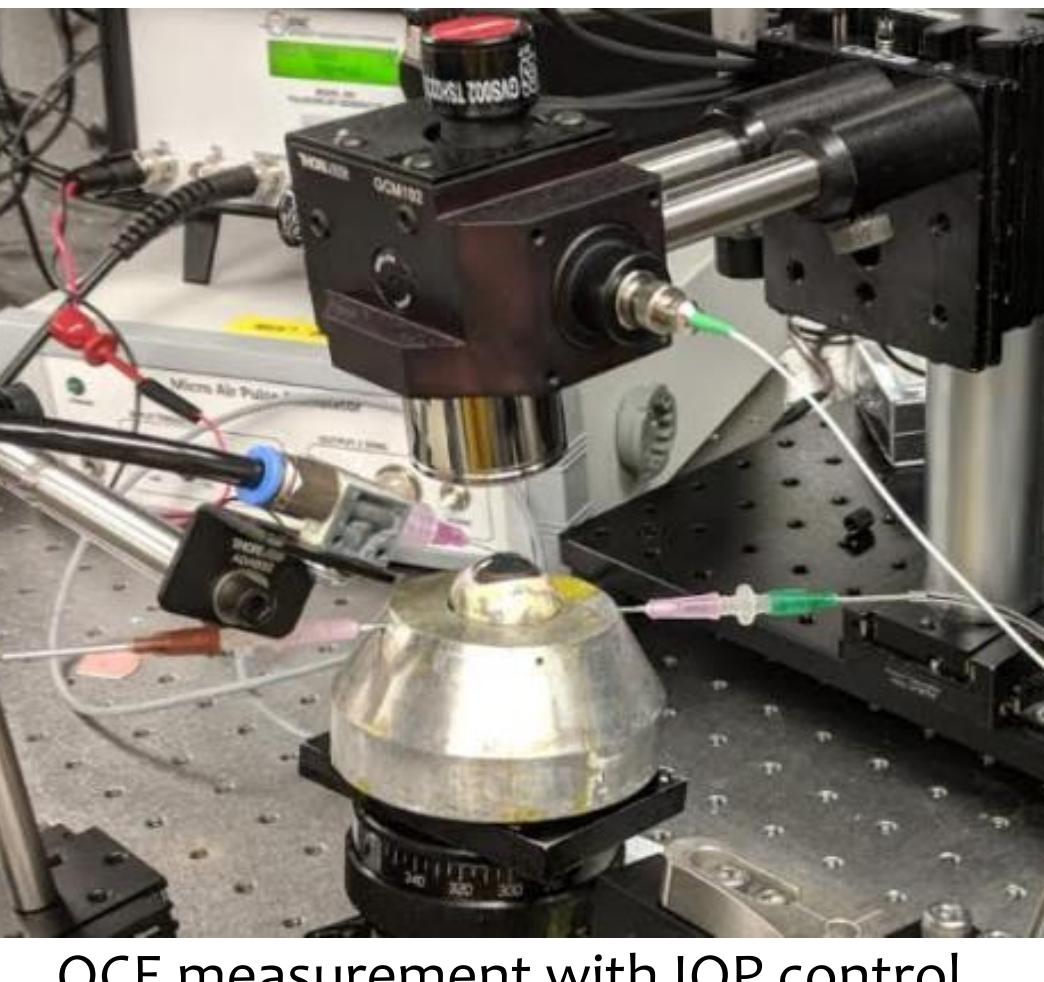
- Keratoconus is a degenerative disease of the cornea that causes corneal softening and vision impairment[1].
- Keratoconus has genetic factors, but similar symptoms can be side effects of LASIK surgery[1,2].
- Corneal collagen cross-linking (CXL) is a recently FDA-approved treatment which combines the application of a photoactivator solution (riboflavin) and ultraviolet (UV) light to the cornea to stiffen the cornea[3].
- Custom CXL applies UV light to only the diseased portion of the cornea, minimizing patient exposure to potentially harmful UV light.
- The biomechanical effects of custom CXL have not been thoroughly tested.
- Optical coherence elastography (OCE) can measure the stiffness of a material by coupling optical coherence tomography (OCT) with the application of an external stress[4,5].
- We quantify the change in stiffness between CXL and untreated regions of an *in situ* porcine cornea.
- We demonstrate that OCE can be utilized to map biomechanical contrast in custom CXL treated corneas.

## Experimental Methods

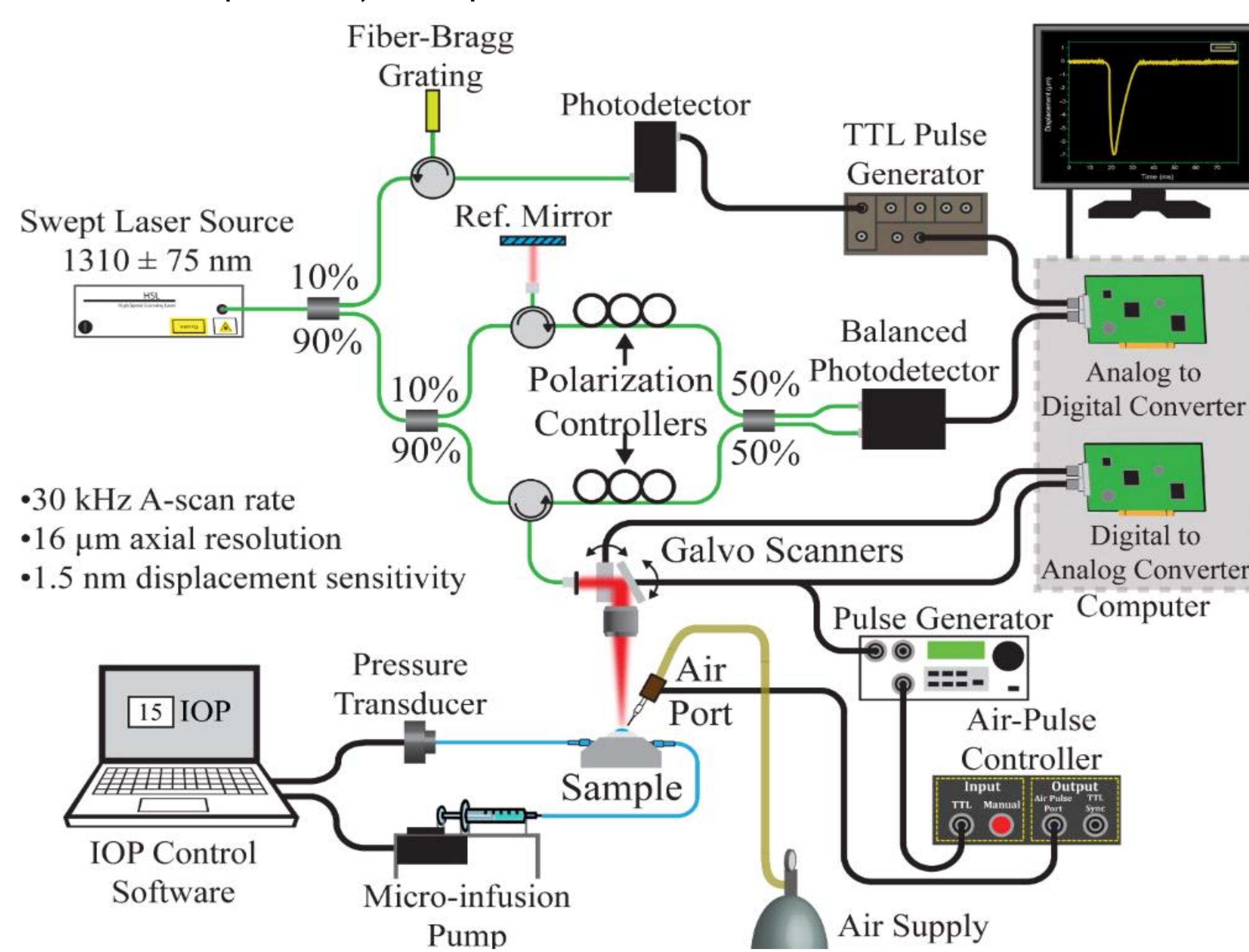
- In order to assess the feasibility of our proposed method, we modeled custom CXL. First, we formed a semispherical phantom split into two regions: One region was composed of 8% gelatin solution, the other of 12% gelatin solution.
- A porcine model was used for tissue measurements. Cross-linking was accomplished by mimicking the “Dresden” protocol[3].
- The intraocular pressure (IOP) was maintained at 10 mmHg.
- OCE measurements were performed by monitoring the displacement of various positions on the corneal surface in response to a focused micro air-pulse.
- For one eye, a circular region was cross-linked. A grid of points were measured using OCE, and the resulting slopes (displacement as a function of excitation pressure) were plotted.



Custom CXL procedure following the “Dresden” protocol [3]



OCE measurement with IOP control



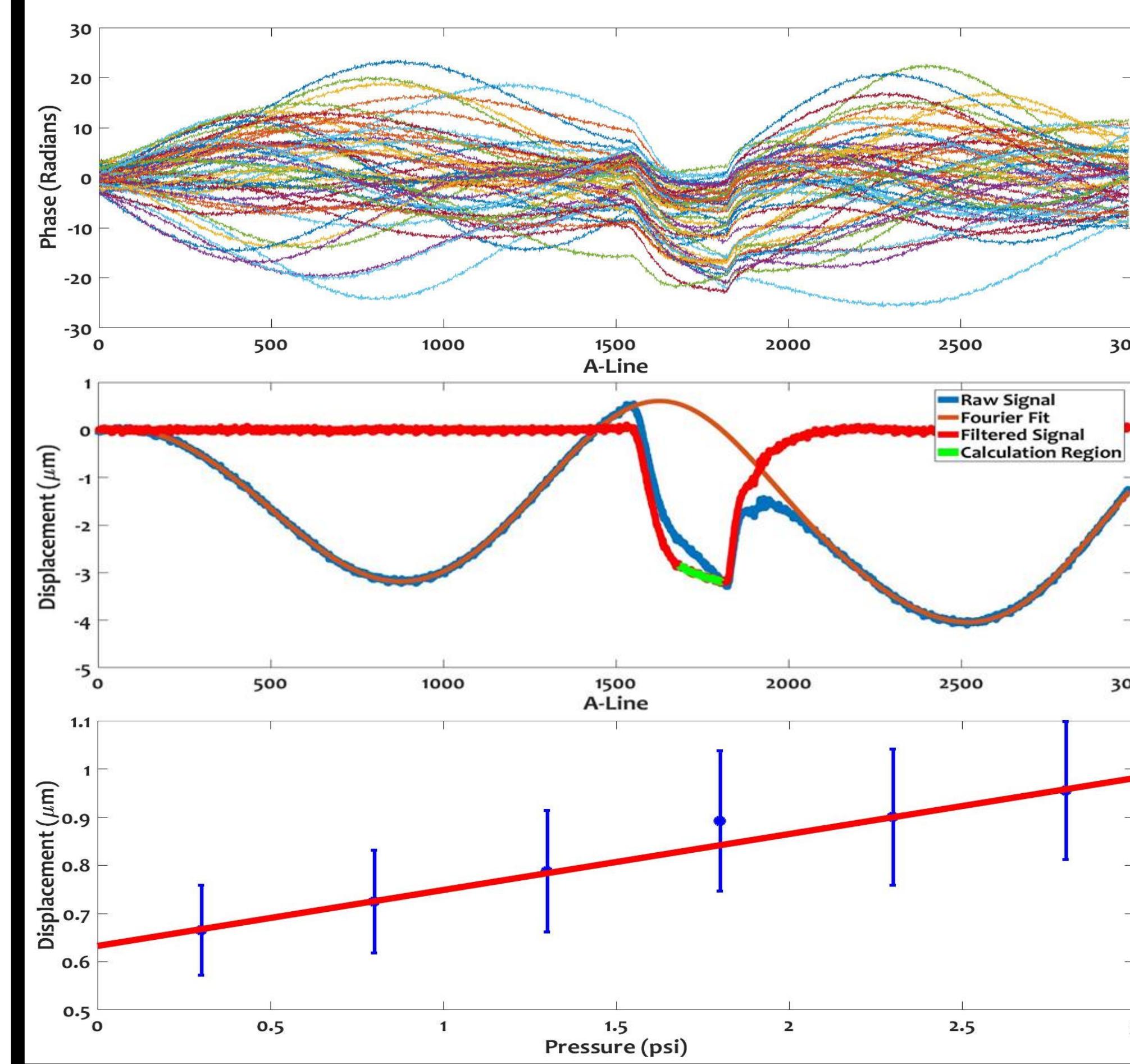
Schematic of the experimental setup, including the OCE system. IOP was maintained via a micro-infusion pump and a pressure transducer. The air-pulse controller produced controlled, periodic pulses of air.

## Acknowledgements and References

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- [2] Wollensak, G., Spoerl, E., Seiler, T., "Stress-strain measurements of human and porcine corneas after riboflavin-ultraviolet-A-induced cross-linking," J Cataract Refract Surg 29(9), 1780-1785(2003).
- [3] Wollensak, G., Spoerl, E., Seiler, T., "Riboflavin/ultraviolet-A-induced collagen crosslinking for the treatment of keratoconus," American journal of ophthalmology 135(5), 620-627(2003).
- [4] Schmitt, J.M., "OCT elastography: imaging microscopic deformation and strain of tissue," Opt. Express 3, 199-211 (1998).
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## Signal Processing

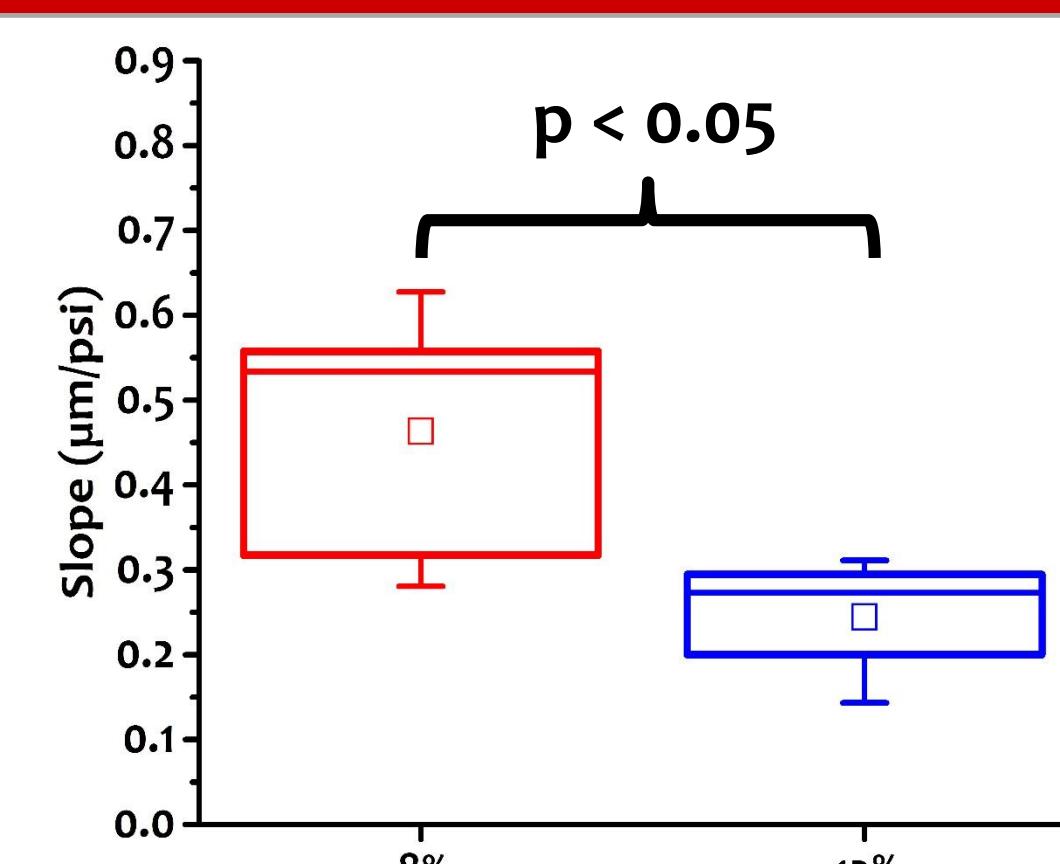


For each pressure measurement, at least 51 displacement profiles were collected via OCE measurements.

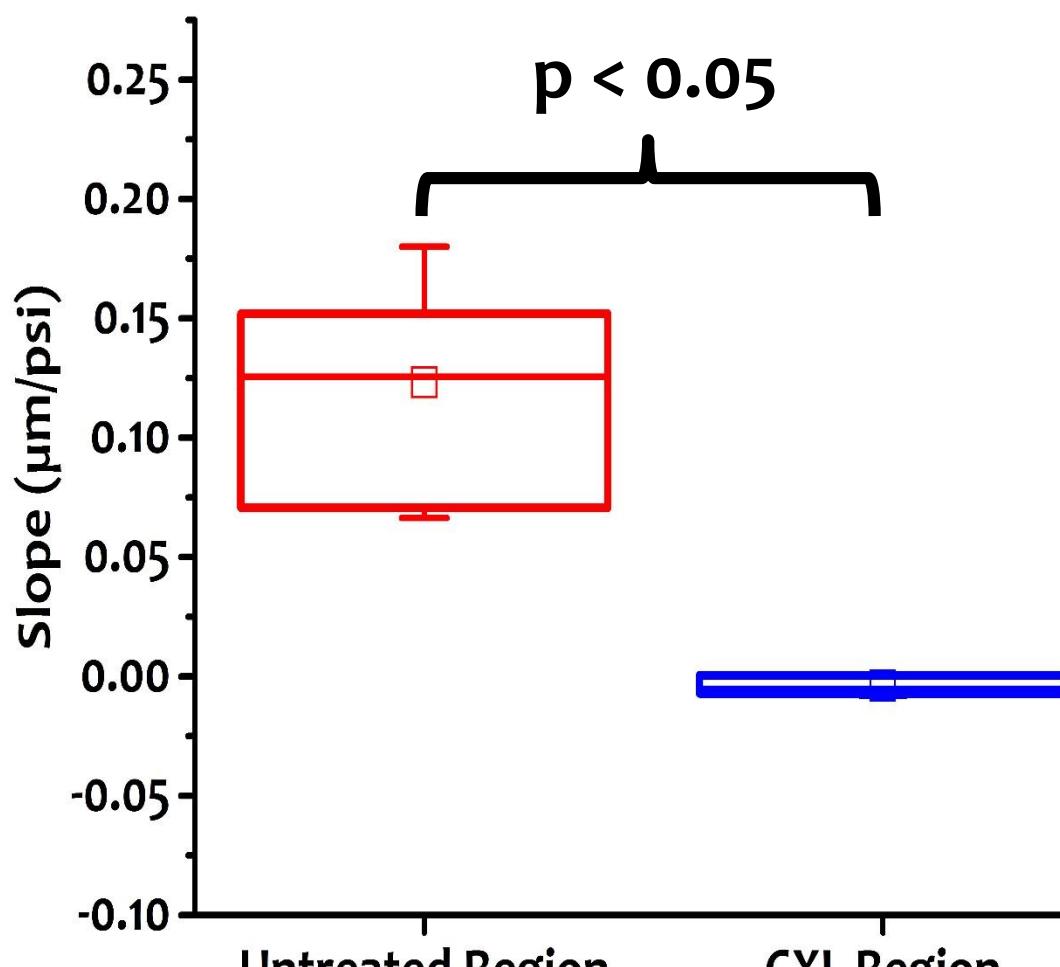
For each individual waveform, the raw (blue) signal was fitted with a Fourier fit (orange) and subtracted from the raw waveform to obtain the filtered (red) signal. The displacement was calculated by averaging the displacement found in the calculation (green) region.

For each position, displacements from all waveforms for all pressures were analyzed. The displacement from before the excitation was calculated as function of excitation pressure.

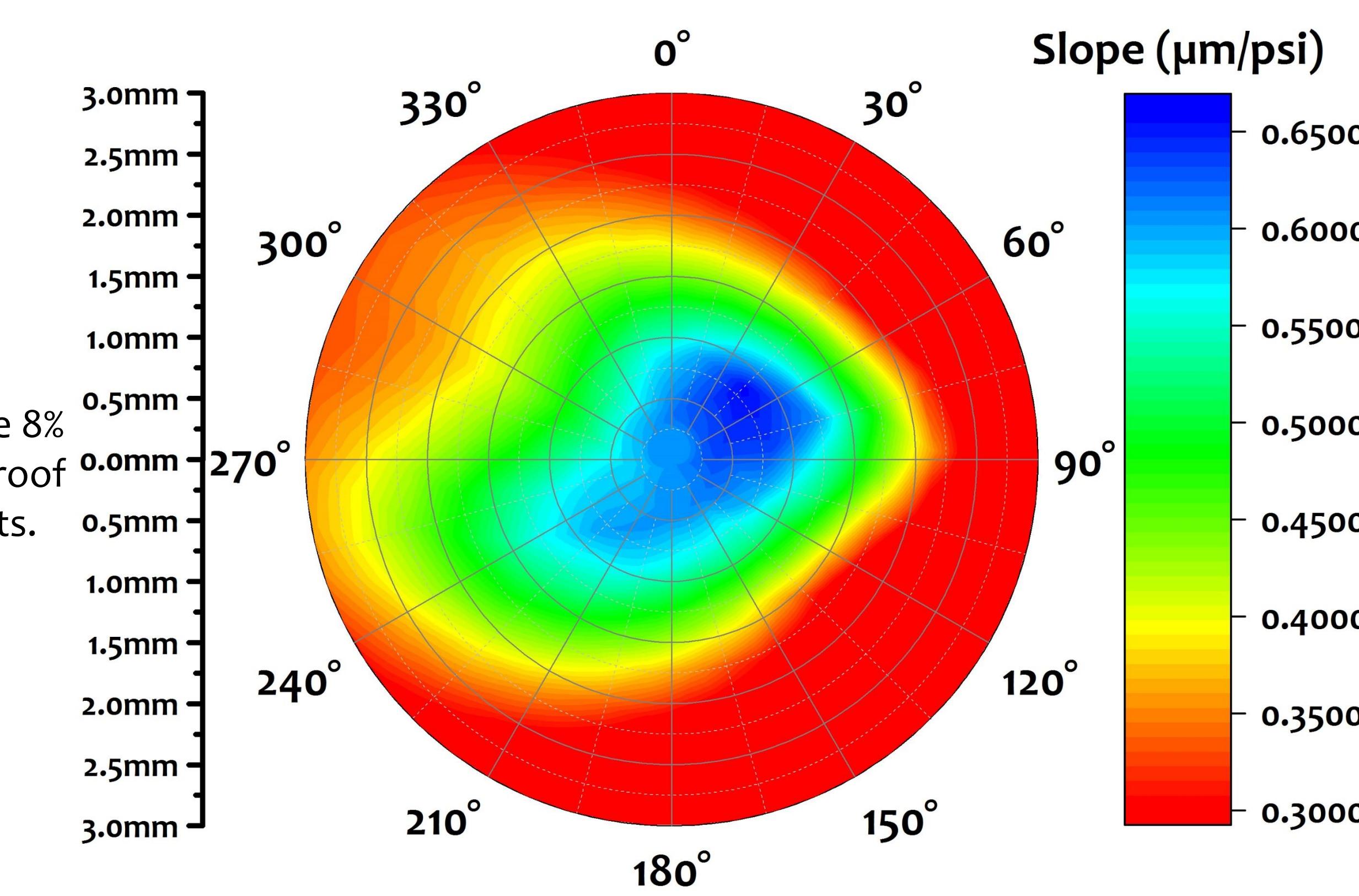
## Results



OCE clearly distinguished between the 8% and 12% gelatin regions, serving as a proof of concept for our tissue experiments.



OCE clearly distinguished between the untreated and CXL regions. Custom CXL clearly creates localized increases in corneal stiffness.



Polar contour plot showing stiffness at the apex of the custom CXL treated porcine cornea. A 2 mm circle at the apex was selected for CXL. The results show a distinct variation in the stiffness of the cornea corresponding to the crosslinked area, but the measured values suggests that the natural curvature of the cornea significantly affects the measurements.

## Conclusions and Future Work

- OCE has potential to map the elastic properties of the custom CXL cornea.
- Custom CXL produces a statistically significant change in corneal stiffness.
- The curvature of the cornea also affects the measured stiffness values.
- Future work will entail developing excitation techniques and instrumentation to eliminate the effects of corneal curvature on the stiffness measurements.
- Future work is also focused on reducing the intra-measurement variance.