FLEXIBLE ELASTOMER OPTICAL WAVEGUIDE FOR WHOLE-GLOBE SCLERAL CROSSLINKING

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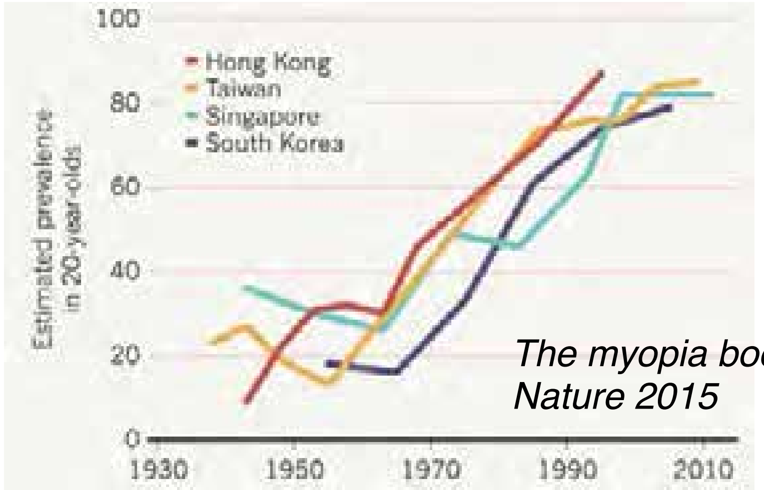
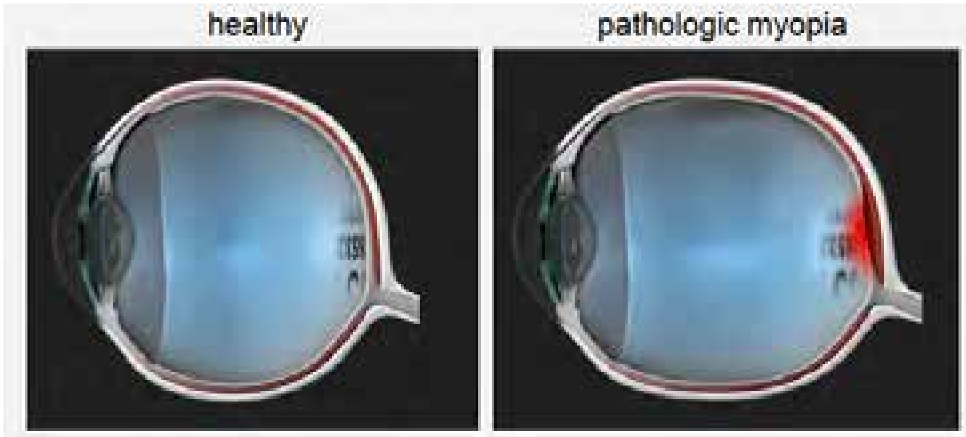
Sclera crosslinking for myopia control

- High prevalence of myopia needs to be addressed with more effective interventions
- Altered sclera biomechanics has been identified in progression of pathologic myopia
- Photochemical crosslinking is a promising technique to arrest scleral elongation and prevent myopia



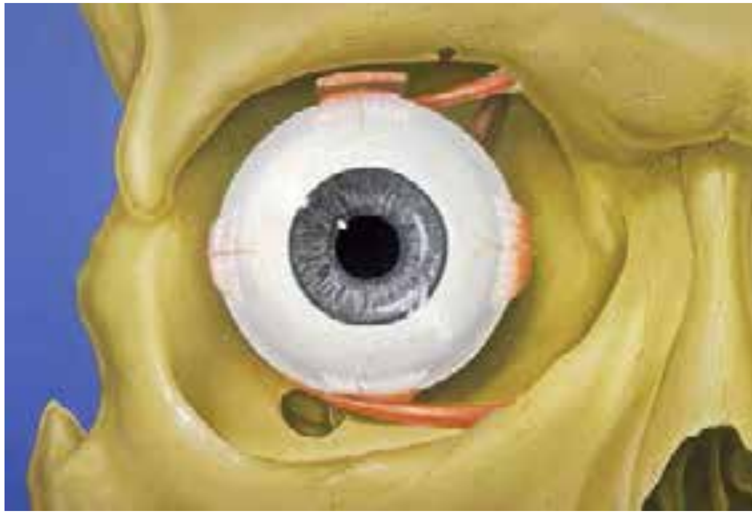
The myopia boom. Nature 2015



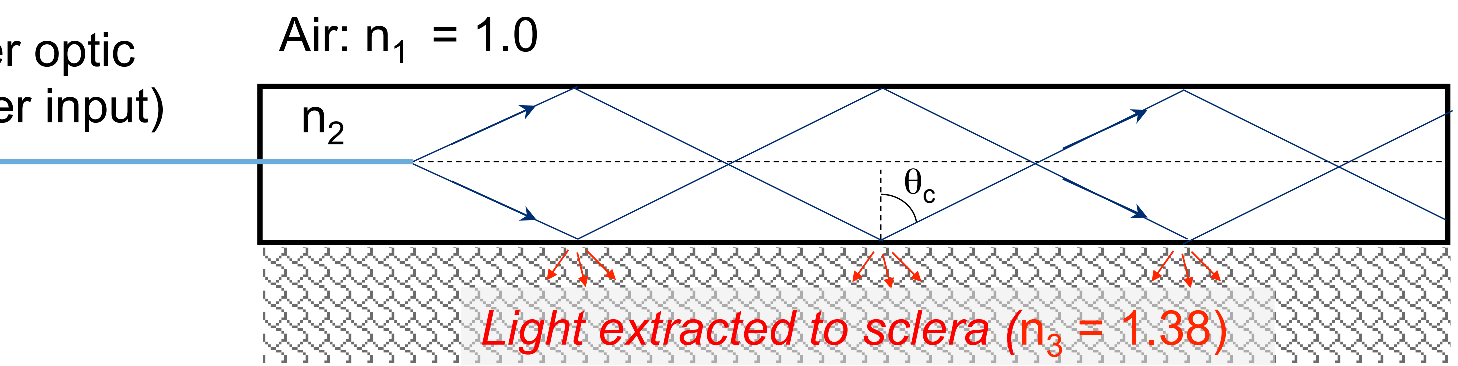
The light delivery challenges

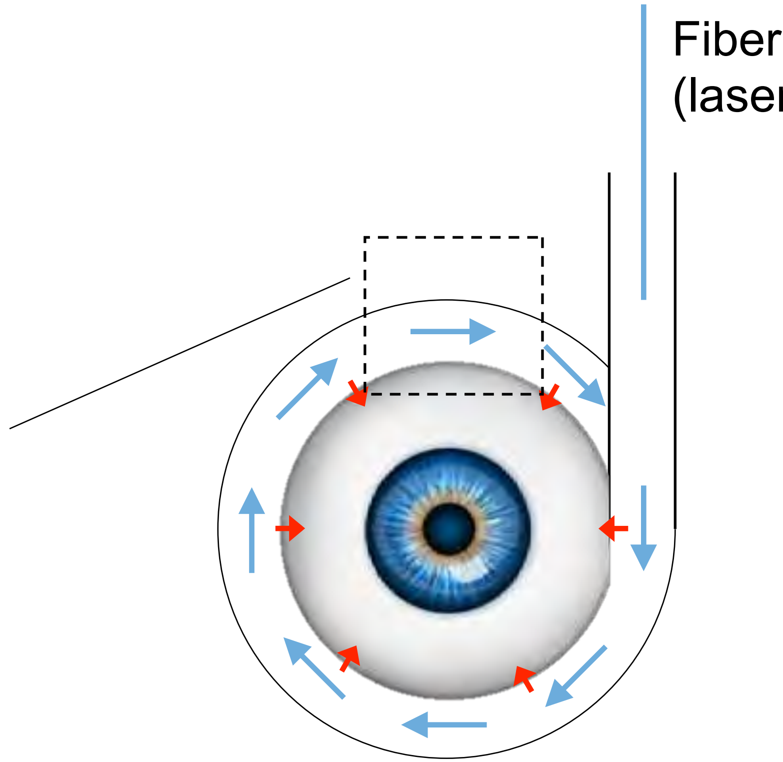
- Whole globe sclera crosslinking (SXL) is challenging
  - Sclera is anatomically difficult to access
  - Uniform light delivery required around the globe
  - Miniature LEDs is a possibility, but they are limited in flexibility and generate heat

- **We propose use of a flexible waveguide optimized for uniform light delivery into the sclera**



The waveguide design





Flexible waveguide to wrap around the eyeball

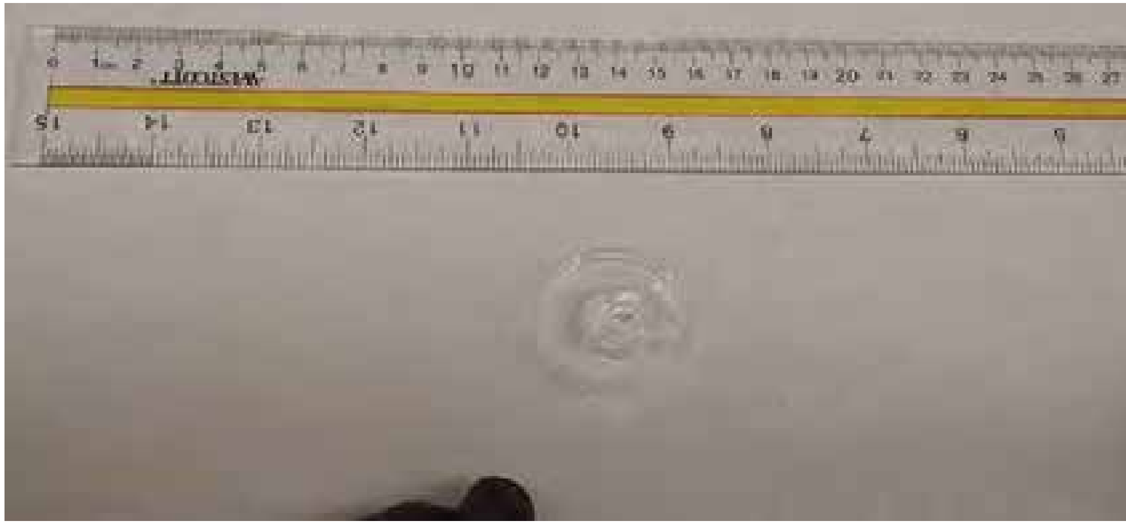
Requires n_2 > 1.38 (sclera) enabling waveguiding by total internal reflection

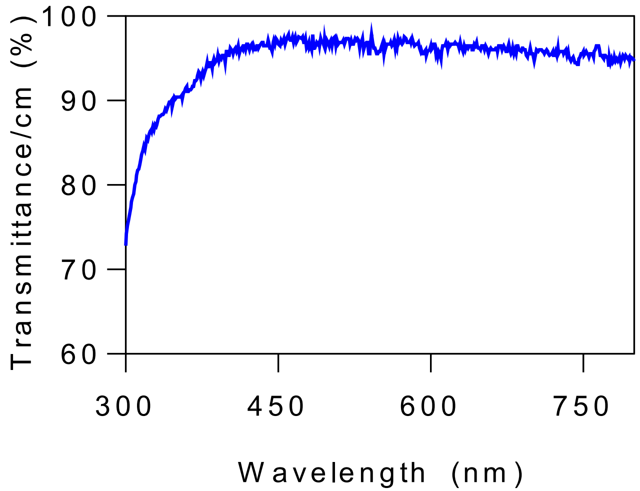
Use of transparent material to minimize light absorption (loss)

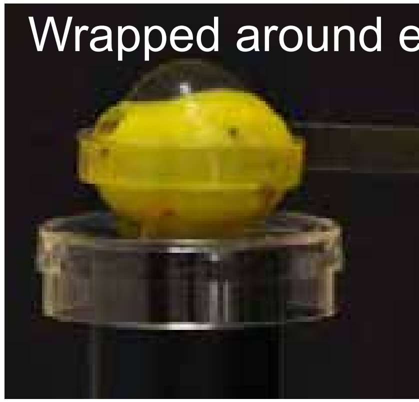
Uniform light delivery to scleral tissue through scattering loss

The waveguide design

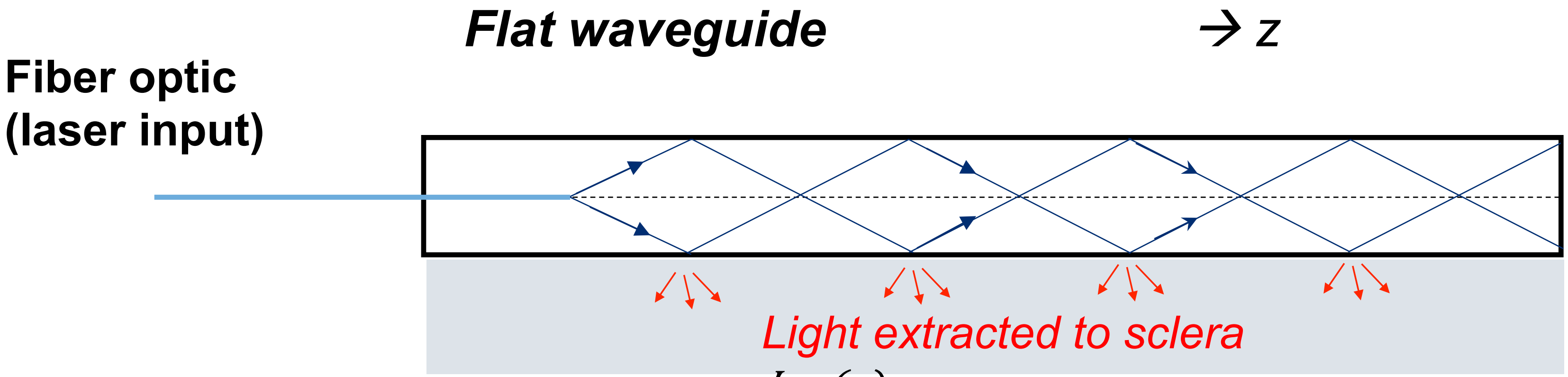
- Made of transparent and flexible PDMS (polydimethylsiloxane)
- $RI_{PDMS} = 1.42 > RI_{sclera} = 1.38$
- Dimensions
  - Length= 70 mm
  - Width= 5 mm
  - Thickness ~ 1 mm



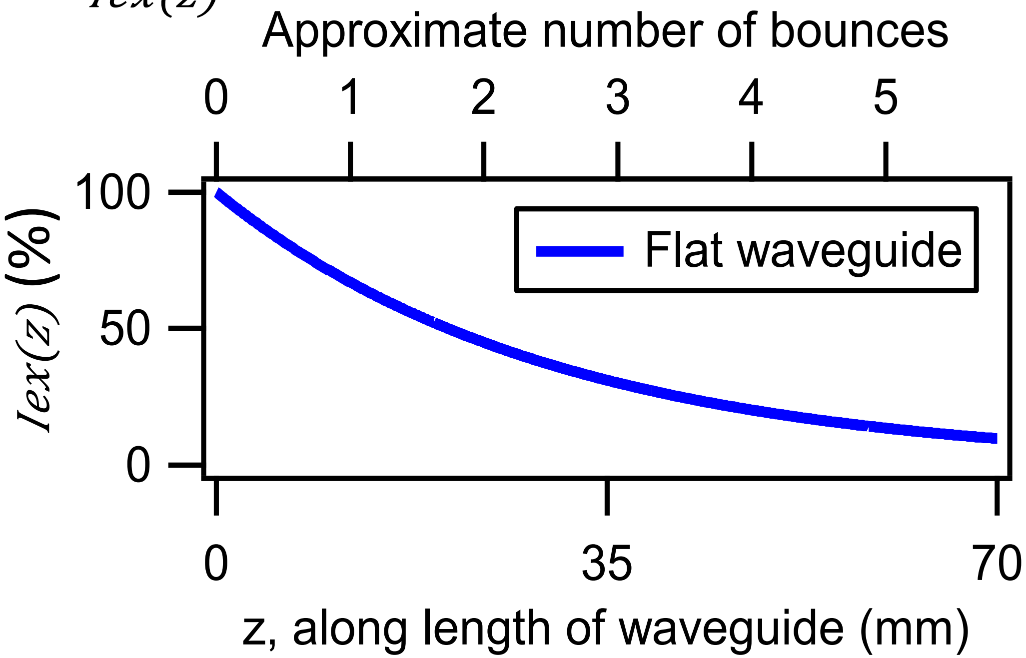




The waveguide design

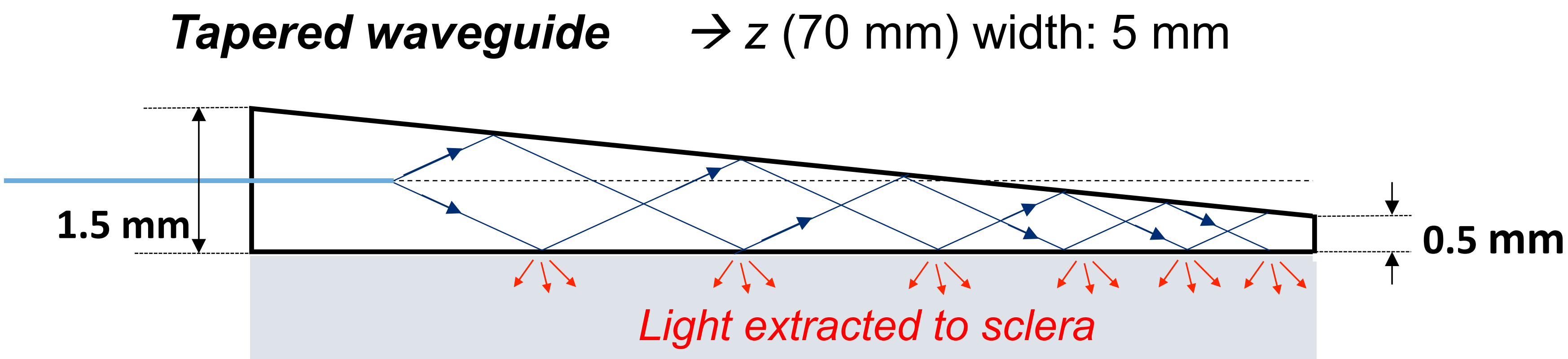


$I_{ex}(z)$

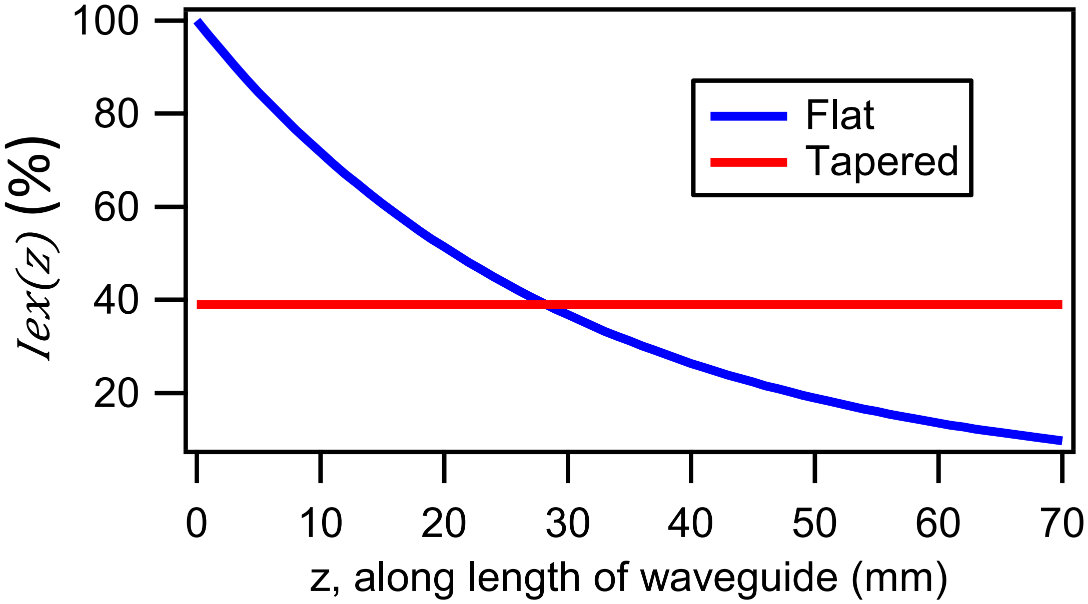


$I_{ex}(z) \propto e^{-\alpha z}$

The waveguide design



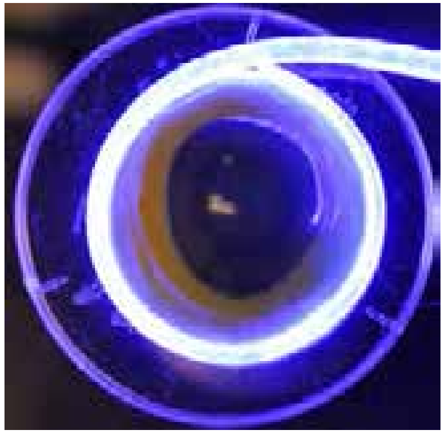
Tapering the waveguide compensates for exponential attenuation:
less bounces in thicker region, more bounces in thinner regions



Periscleral crosslinking with riboflavin and blue light

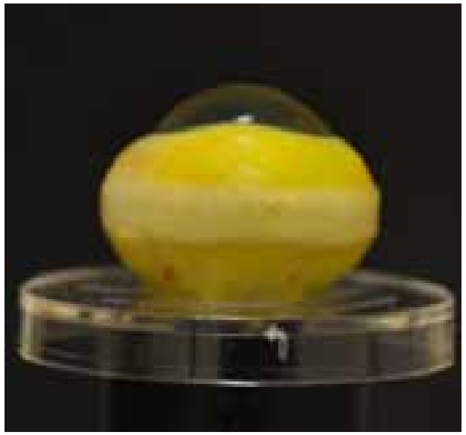
- Fresh porcine eyes stained with 0.5% riboflavin solution for 30 minutes
- Illumination with 450 nm at 25-50 mW/cm^2 for 30 minutes
- Fluorescence intensity was monitored during SXL
- Scleral strips were acquired after SXL and analyzed by tensiometry

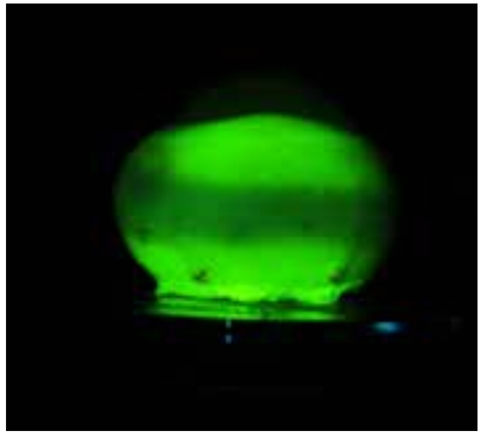
450 nm excitation



Riboflavin fluorescence

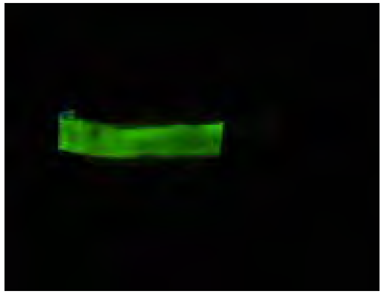
After photobleaching

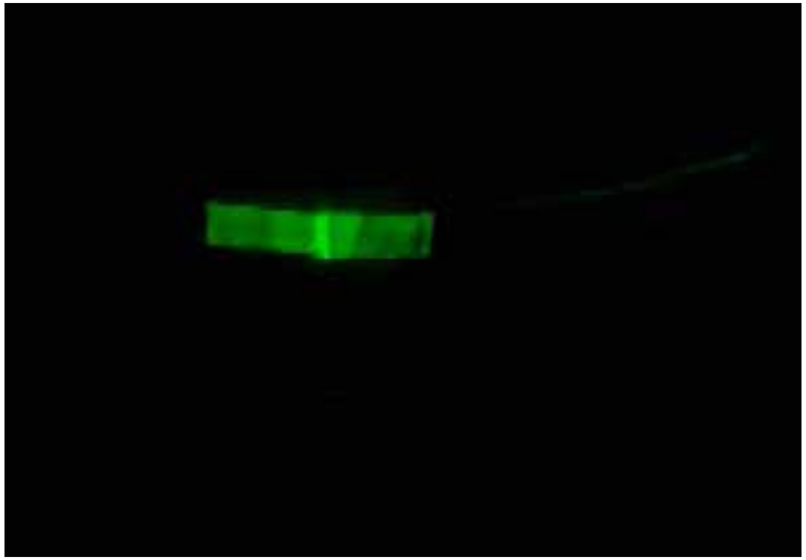


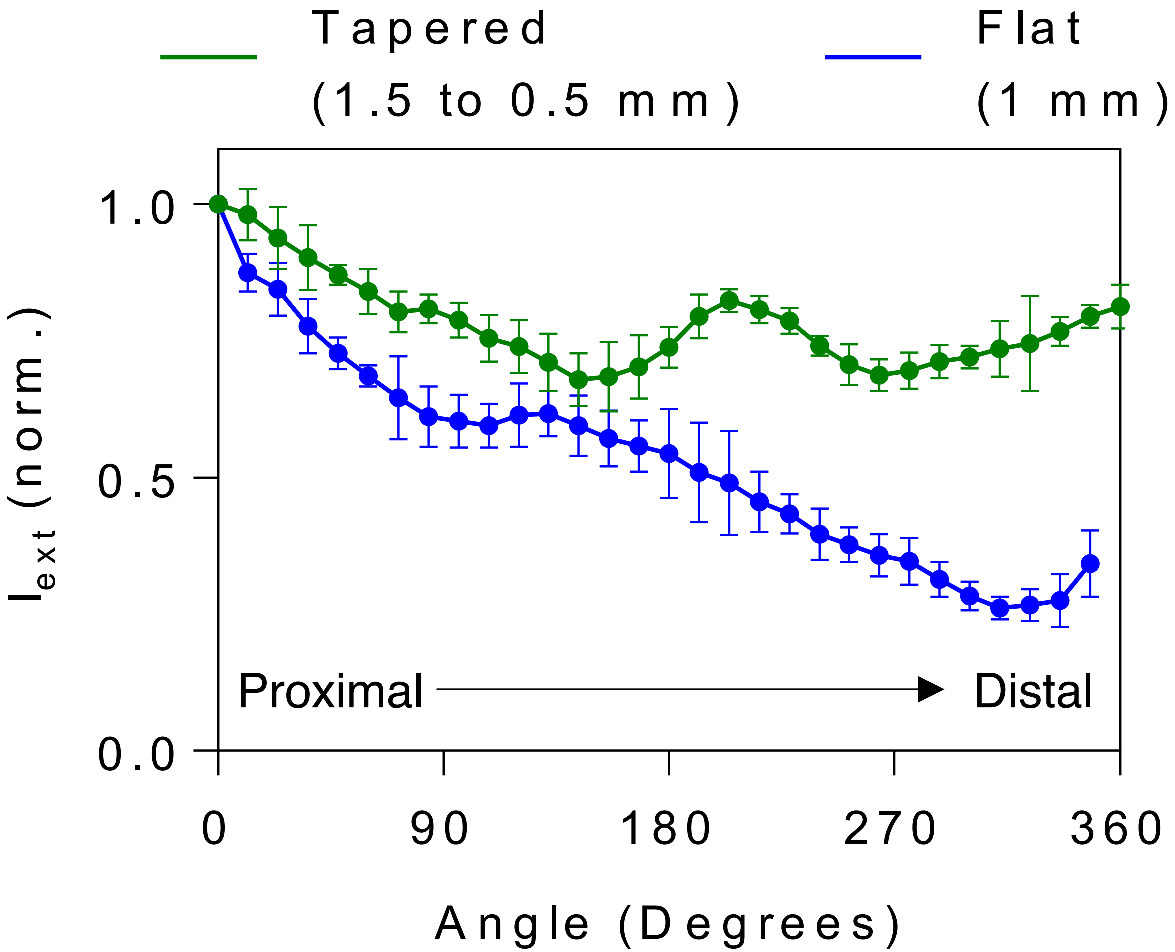


Obtaining uniform light delivery

rescence distribution around the globe

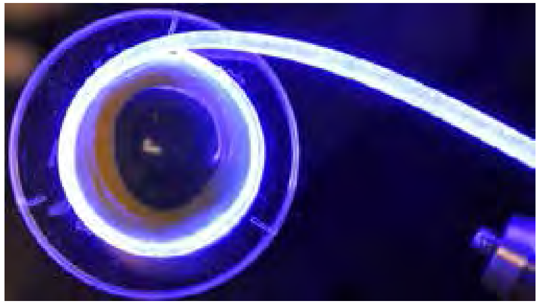




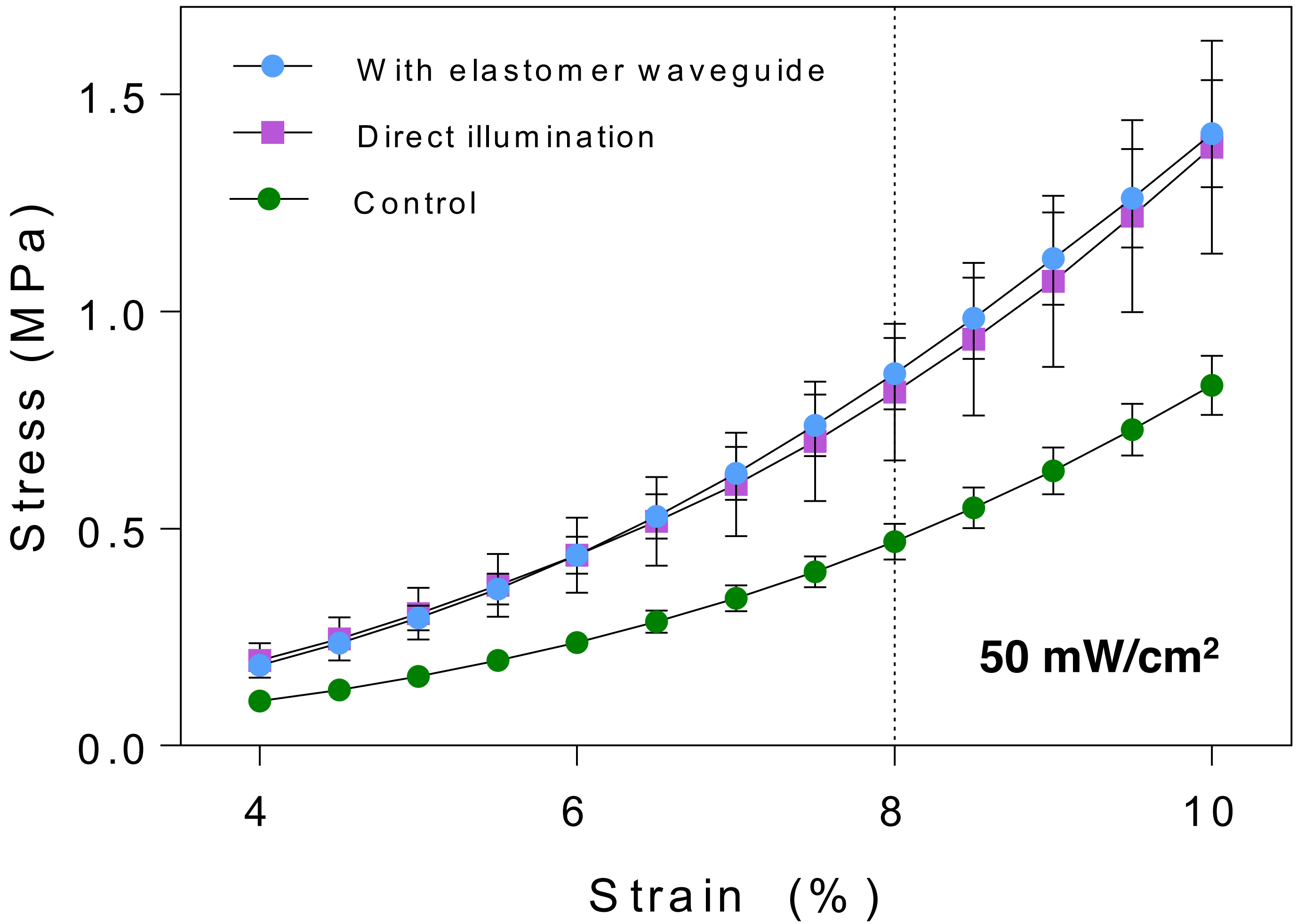


Tensiometry results

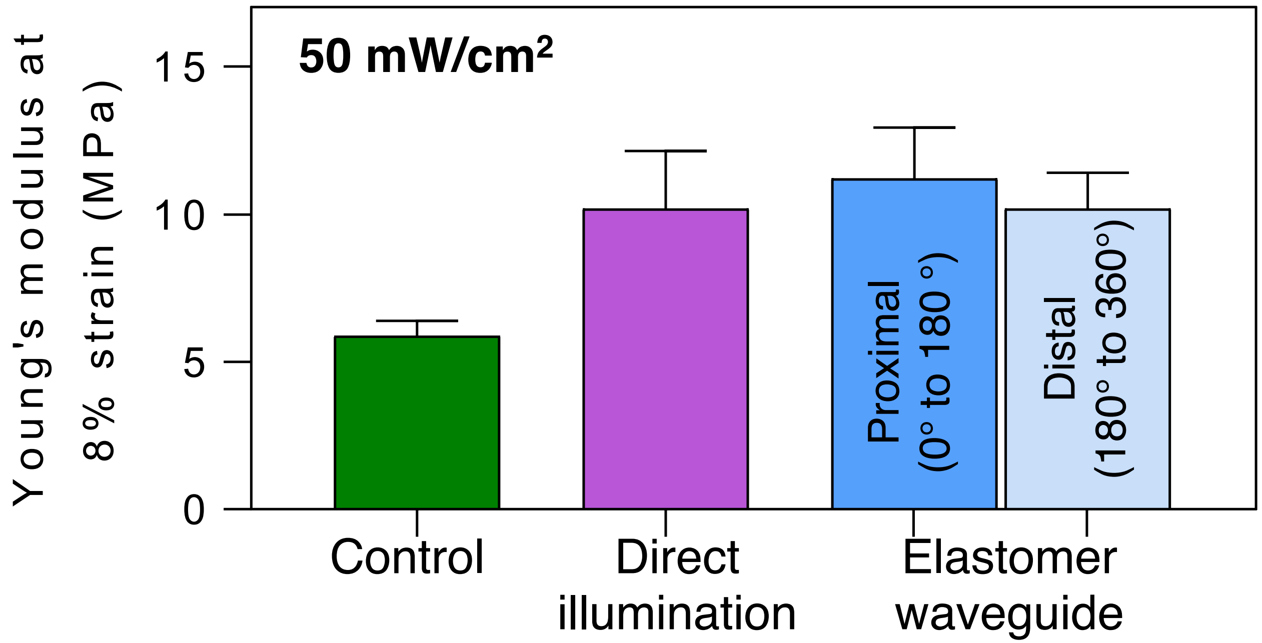
Elastomer waveguide

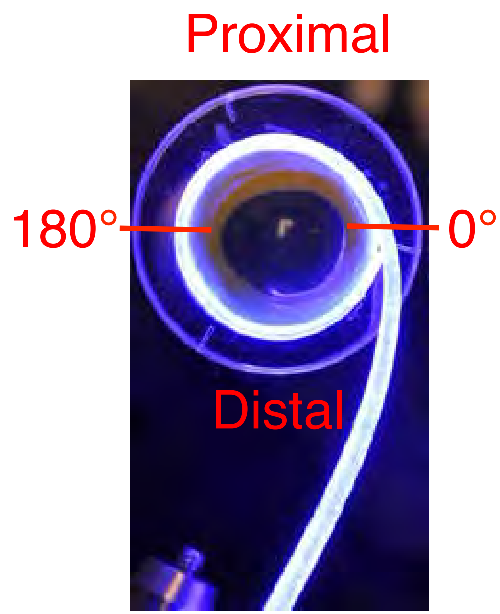


Direct laser illumination



Tensiometry results





XL with blue light, 50 mW/cm² resulted in a 1.8-fold increase in the Young's modulus at 8% strai
o significant difference between direct illumination and with elastomer waveguide
o significant difference between proximal (0° to 180°) and distal (180 ° to 360 °)

Conclusions & future work

- We demonstrated periscleral crosslinking of porcine eyeballs with flexible elastomer waveguide resulting in a ~2-fold increase in Young's modulus
- Further optimization of waveguide geometry and irradiation parameters will improve light uniformity
- Future experiments include SXL with waveguides *in vivo*

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The authors have patents and invention disclosures on related technologies

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