UNIVERSITY OF HELSINKI

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Simulation of Acoustically Excited Membrane Waves on an Eye

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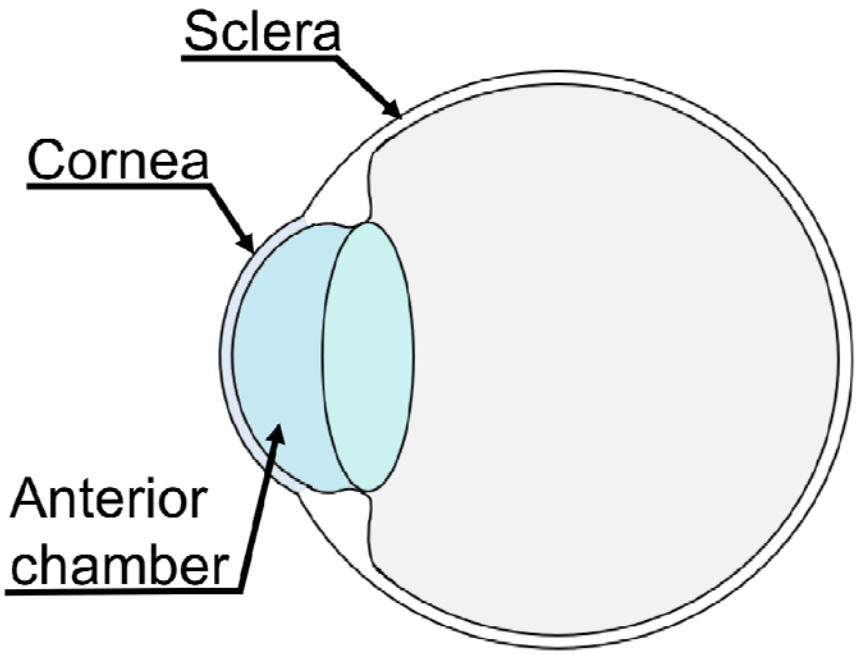
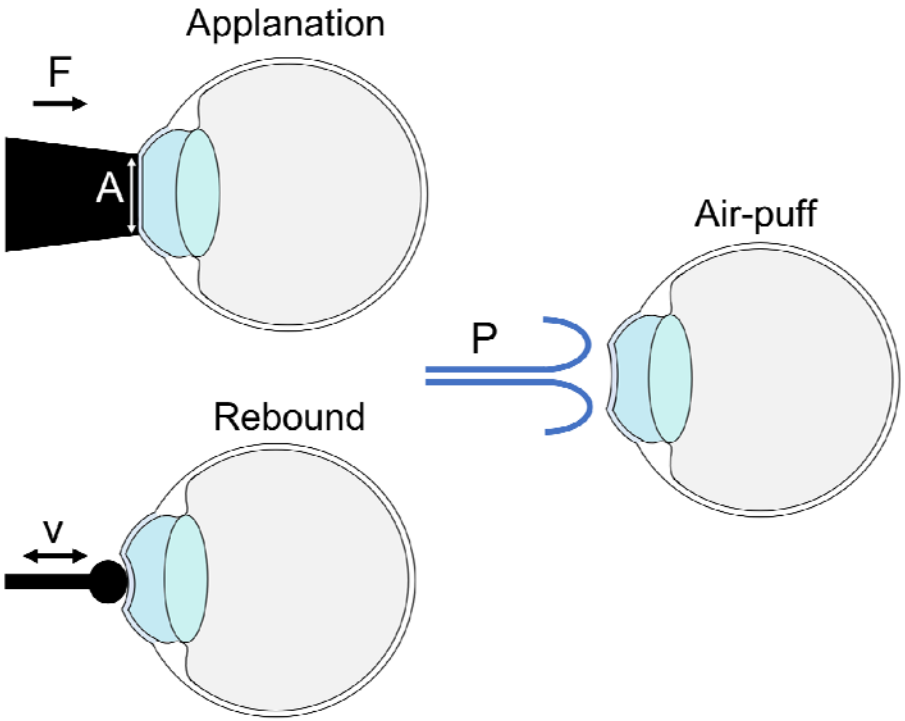
Intraocular pressure (IOP) and glaucoma

- Glaucoma is a type of eye diseases that can lead to blindness
- One of the risk factors for glaucoma is a raised IOP value
- Typical value for a healthy person is approximately 16 mmHg
  - Glaucoma risk when clearly over 20 mmHg
  - Variation between individuals



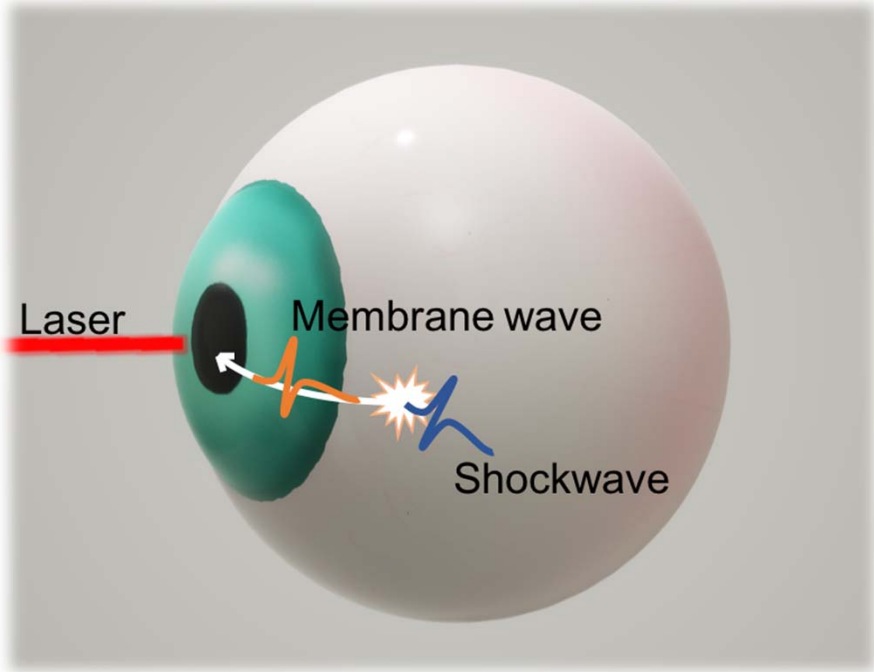
IOP measurement techniques

- Different ways to determine the IOP include:
  - Applanation tonometry
  - Rebound tonometry
  - Air-puff tonometry
  - Etc.
- Air-puff tonometry is considered non-contacting but is based on applanation
- Our method based on wave propagation is both non-contacting and patient friendly

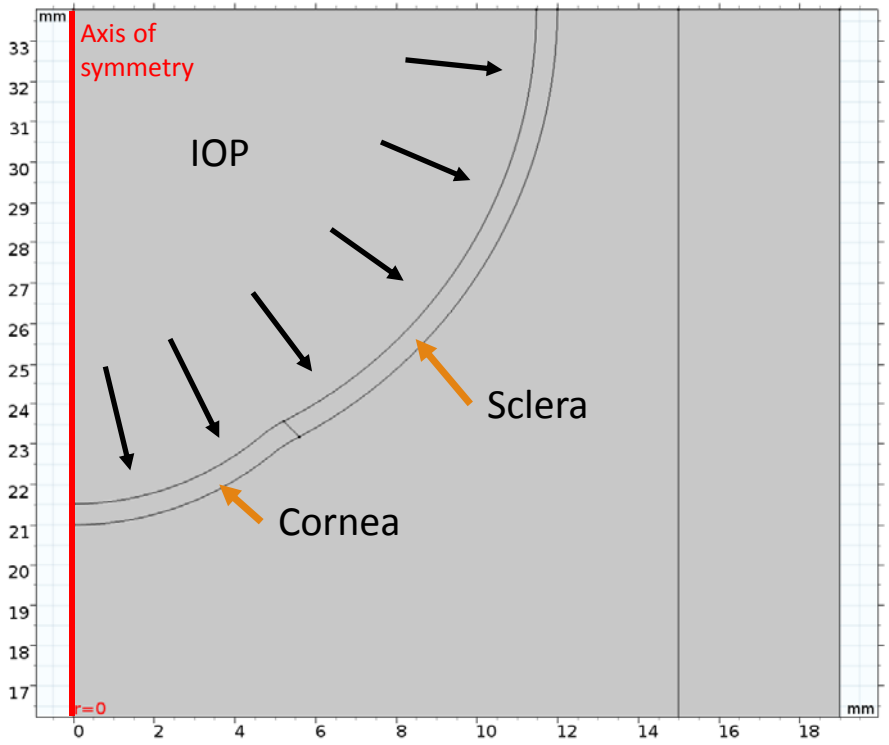


Using COMSOL to model our set-up

- Two main parts to model:
  - How the time-of-flight of a wave on the eye depends on IOP?
  - **How is the wave generated through shockwave interaction on the eye?**



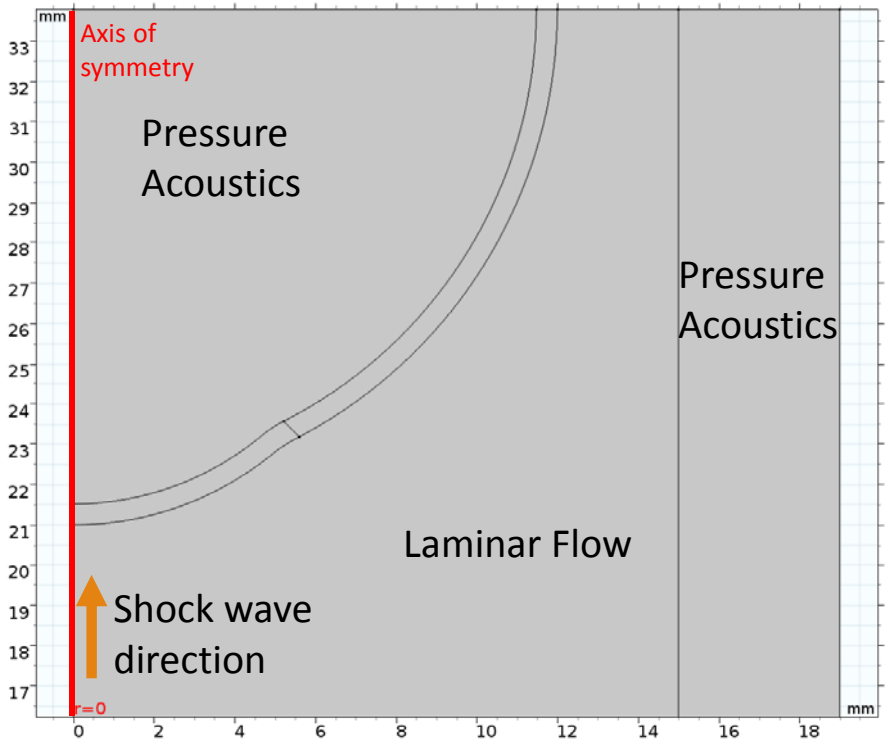
COMSOL model for acoustic excitation – the eye



- Axial symmetry was used to reduce the size of the simulation domain
- The eye was modeled as a hyperelastic material in the Solid Mechanics module
- Reported values for corneal Young's modulus range from ~20 kPa - 20 MPa [1]
- Young's Modulus of the sclera also has a wide range of reported values ~2 MPa - 70 MPa [1]

[1] D. L. Hugar, A. Ivanisevic, Materials characterization and mechanobiology of the eye, *Materials Science and Engineering C*, 33, 2013

COMSOL model for acoustic excitation – fluid domains

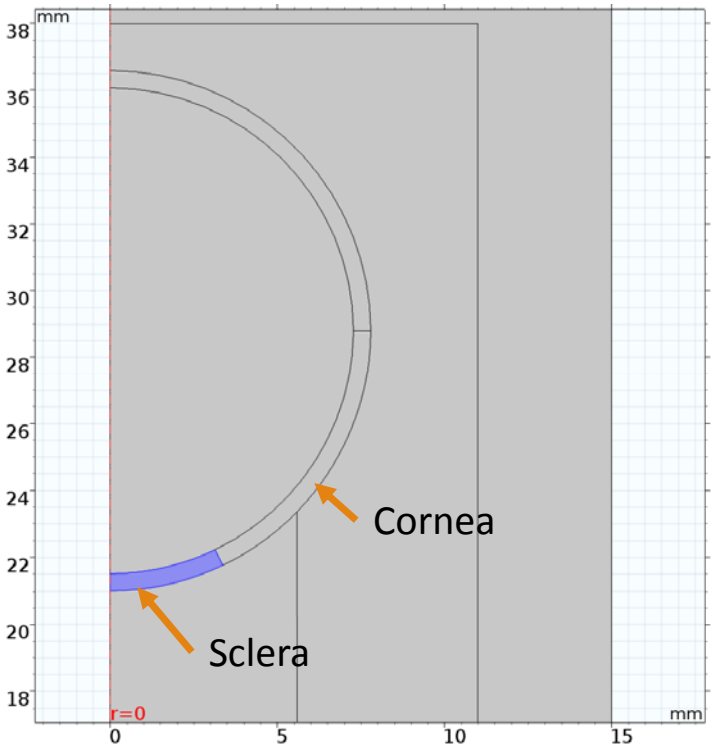


- Fluid domains were modeled using the CFD module and the Pressure Acoustics module
- Laminar Flow interface was used for the (relatively weak) shockwave propagation
  - Compressible flow with non-linear density – pressure dependency

$$\rho = \rho_0 + \frac{p}{c_0^2} - \frac{1}{\rho_0 c_0^4}(\beta - 1)p^2$$

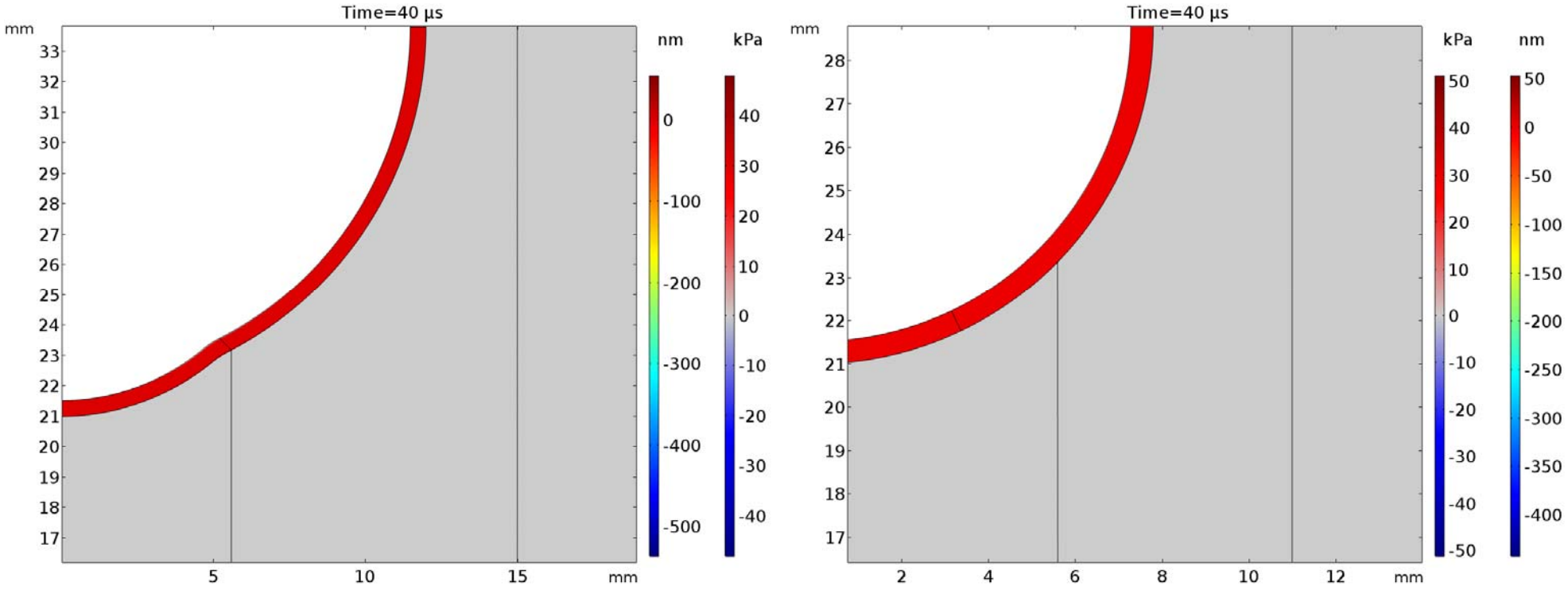
$$\rho_0 = 1.2\frac{kg}{m^3}, c_0 = 343\frac{m}{s}, \beta = 1.4$$

Excitation in the sclera



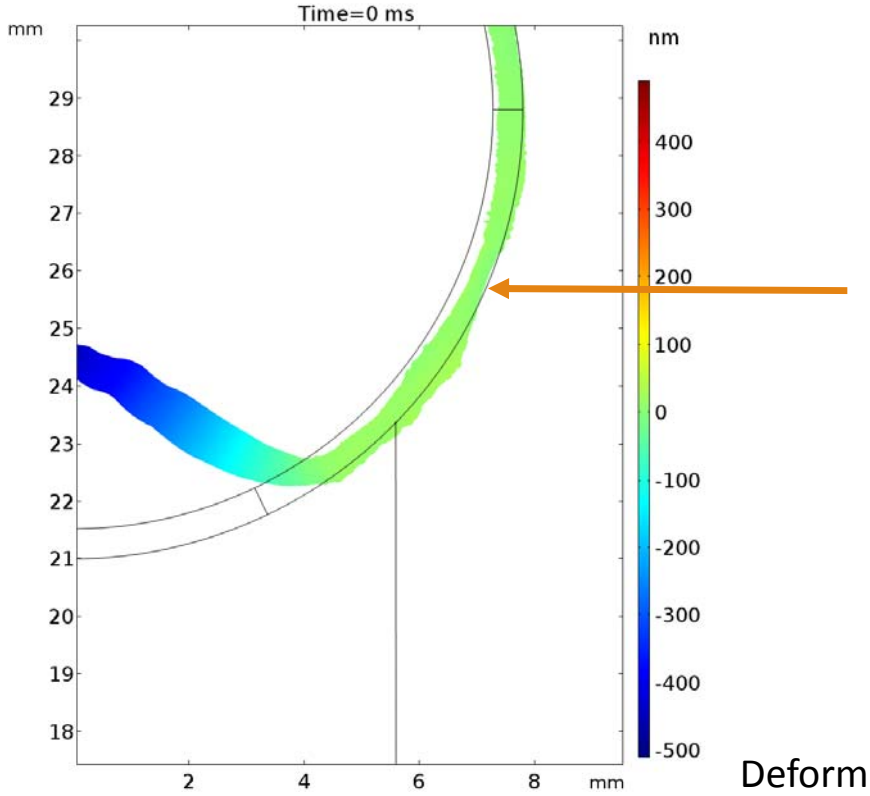
- Without simulating a full 3D model the geometry has to be simplified for scleral excitation
- Elastic modulus of the sclera is higher than in the cornea, thus this affects the excitation

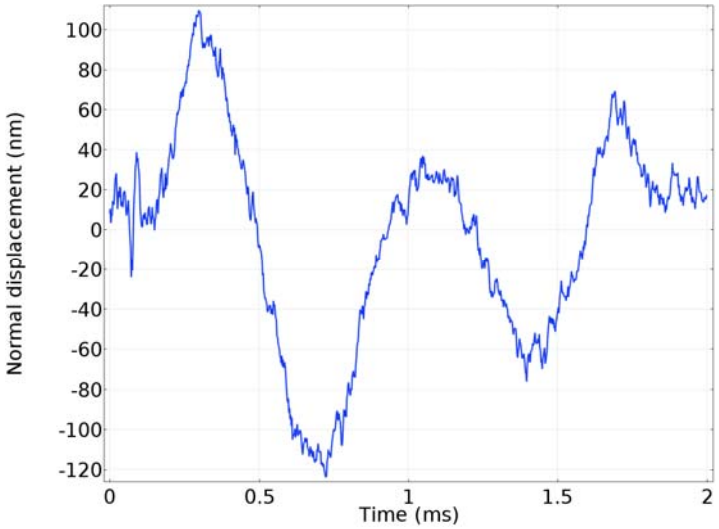
Results - excitation



Deformation x5000

Results – membrane wave propagation





Deformation x7500

Conclusions

- A model to simulate shockwave based membrane wave excitation on an eye was presented
- Challenges in modeling with biological parameters and shockwaves was discussed
- Future work:
  - More detailed model of the eye
  - A 3D model is needed for a complete model of the system