Generation and In Situ Modification of Customized IOLs

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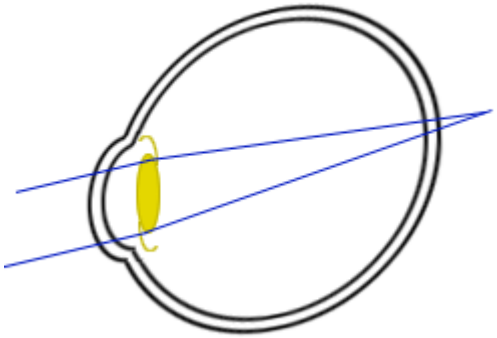
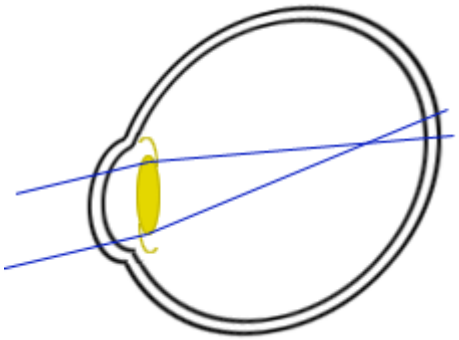
- Refractive Index Shaping (RIS)
- The Instrument
- Phase Wrapping Algorithm
- Aspheric / Toric IOLs

Motivation

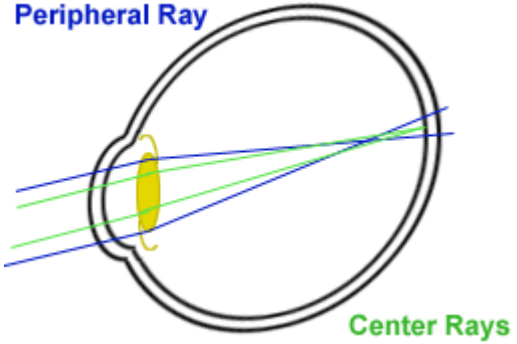
Before:



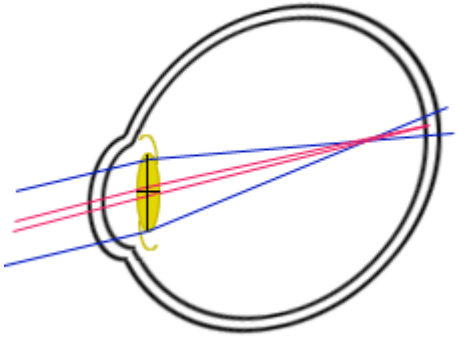
Hyperopia



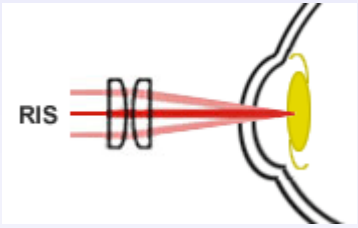
Myopia



Spherical Aberration

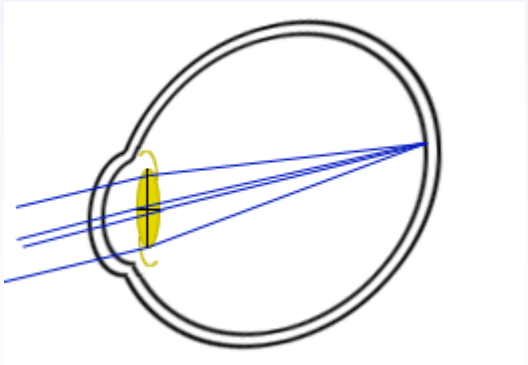


Astigmatism



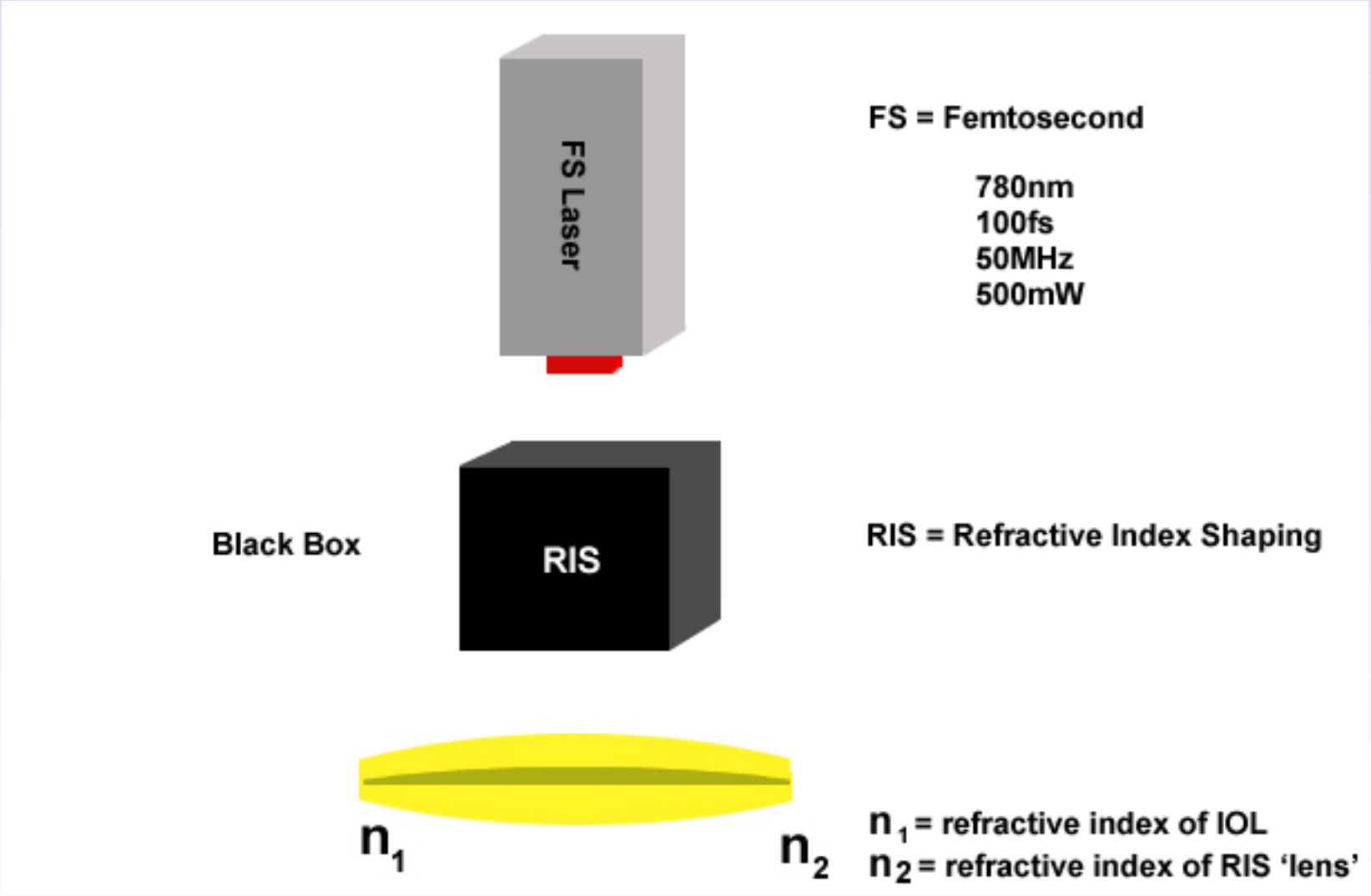
“Lens“ modification

After:



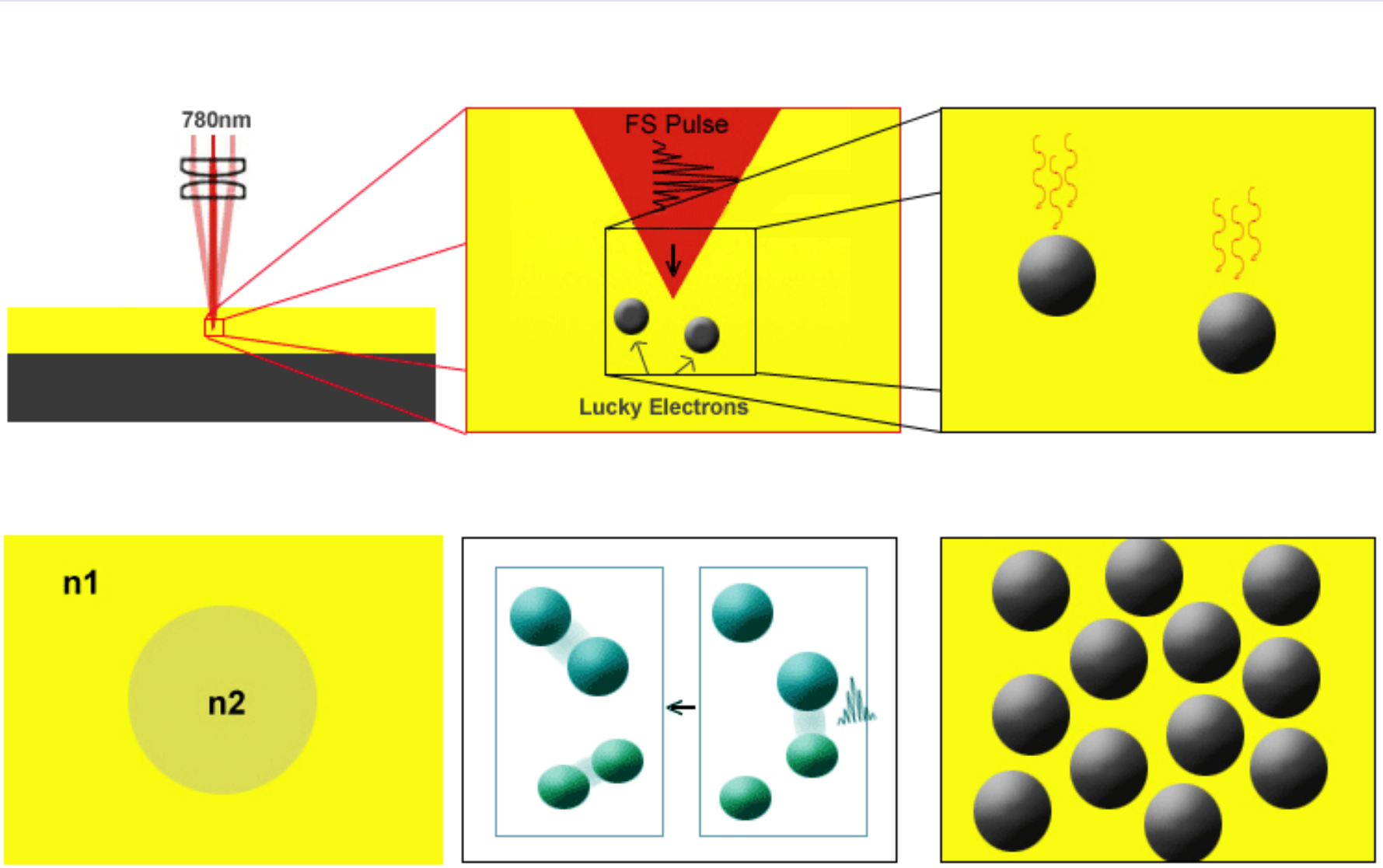
Perfect Vision

Concept



RIS changes the optical properties without cutting

Refractive Index Shaping (RIS)



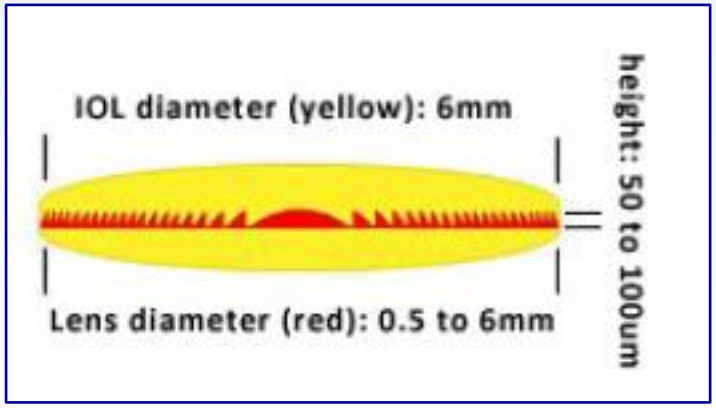
RIS Key Points

•“Lens“ is referred to as the area of the IOL which is treated with Refractive Index Shaping to alter the refractive index of the IOL.

•The refractive index of the “Lens“ is higher than the refractive index of the surrounding IOL material.

•The shape of the “Lens“ is determined by the pattern of laser beams hitting the target area inside the IOL.

•The diopter change in the IOL is due to the combination of refractive index change within the “Lens“and the three-dimensional shape of the “Lens“.



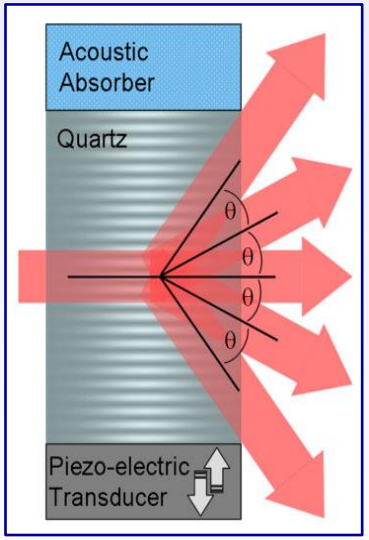
2 Photon Microscope with 500mW Laser

The Instrument

AOM

(Acousto Optic Modulator)

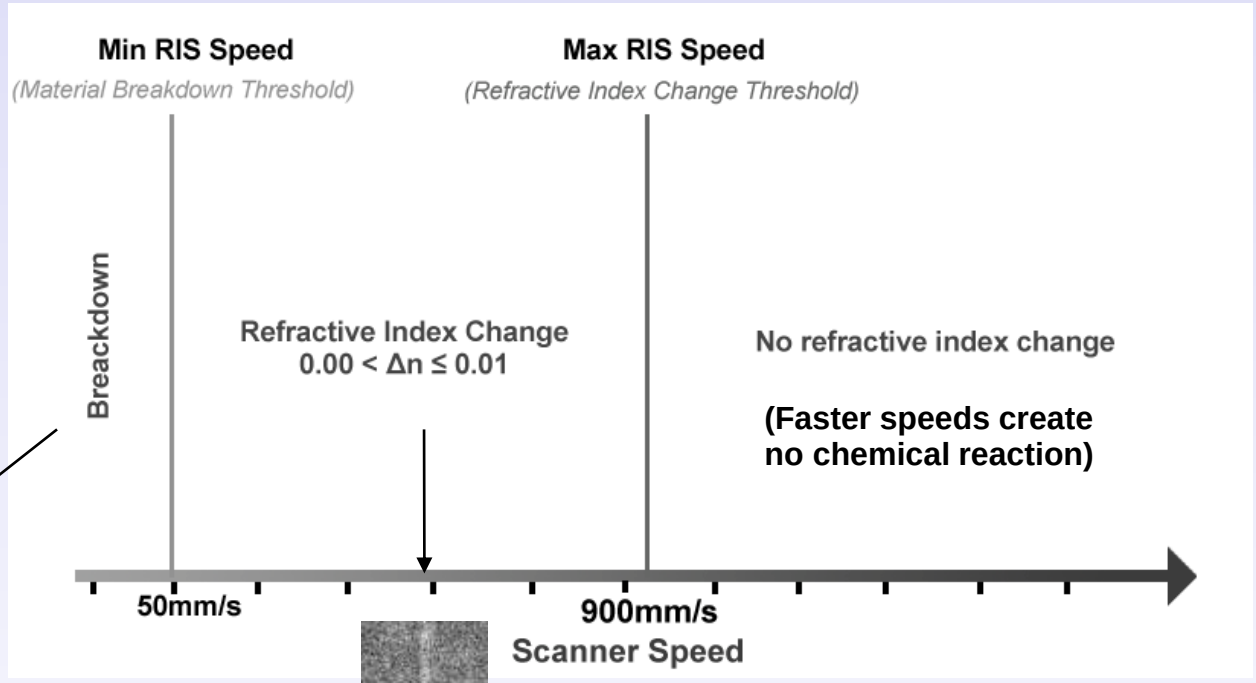
500mW Laser



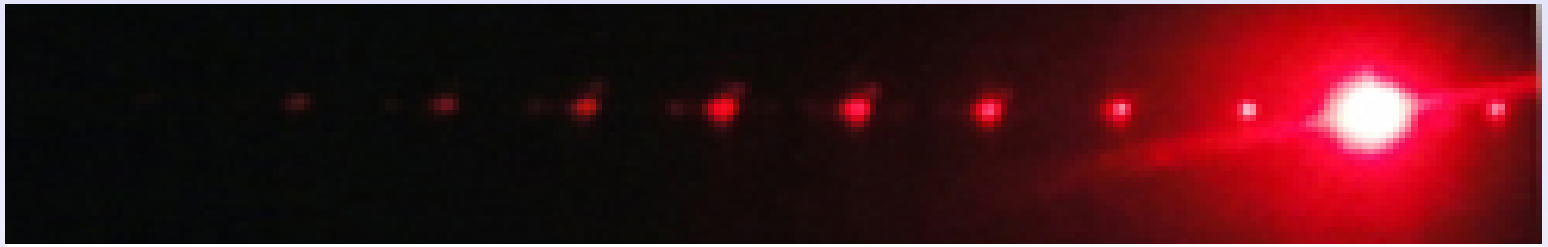
The AOM allows the instrument to variably treat 10 million spots per second inside a designated area

RIS Max and Min Speed

(Slower speeds destroy the IOL material)

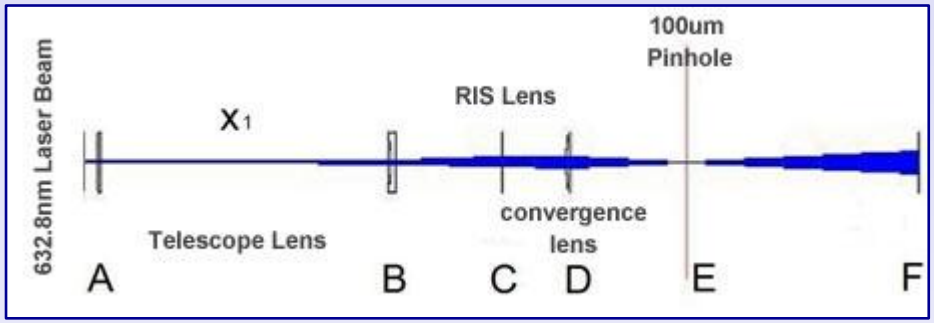


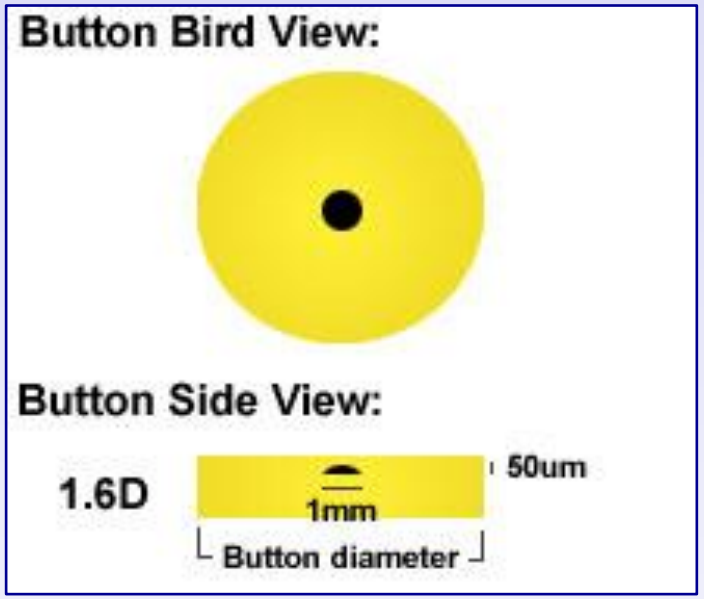
Refractive Index Change Calculation

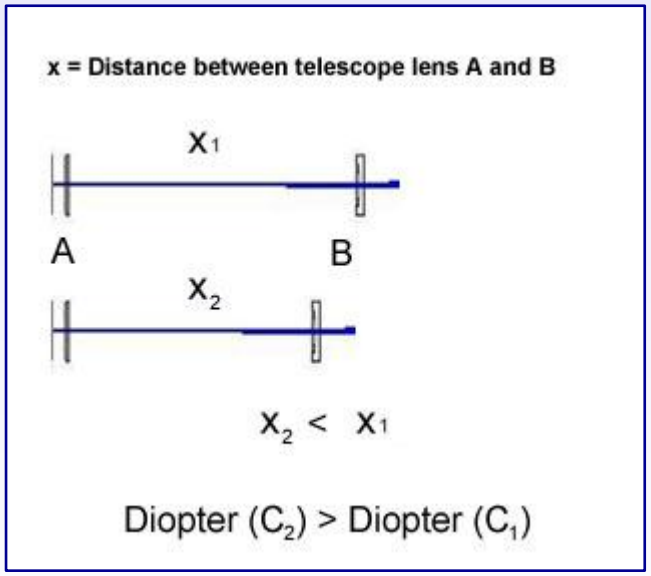


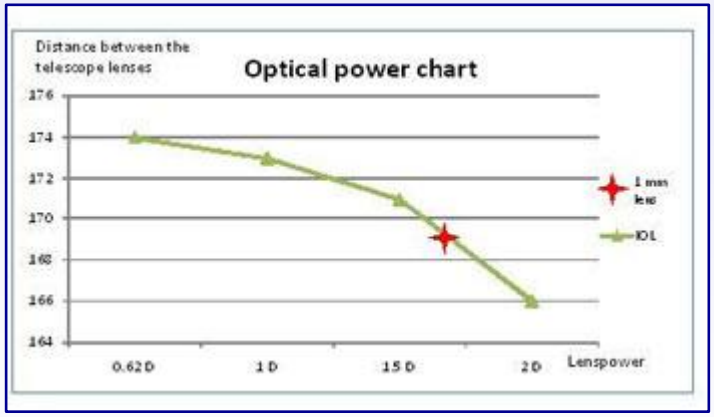
$$\Delta n = \frac{\lambda \cos(\Theta) \tanh^{-1}(\sqrt{(\eta)})}{\pi h}$$

Refractive Index Change





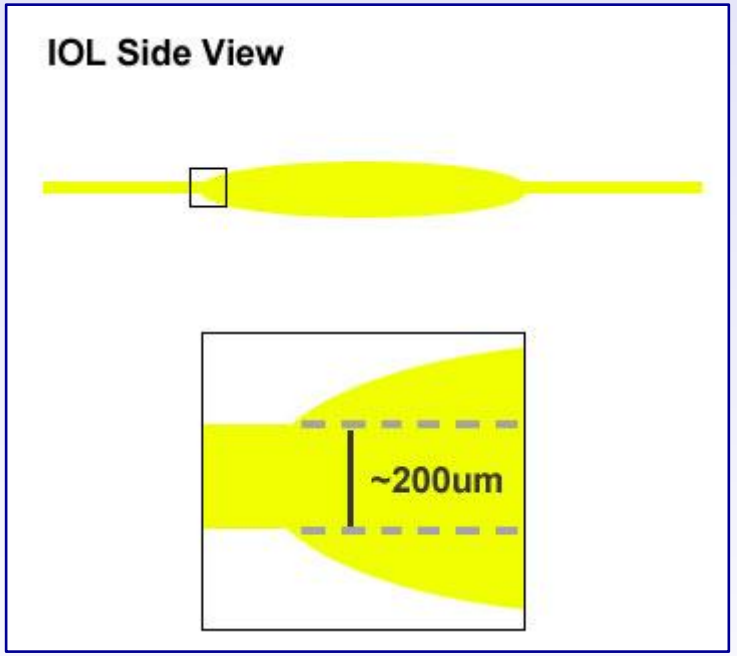




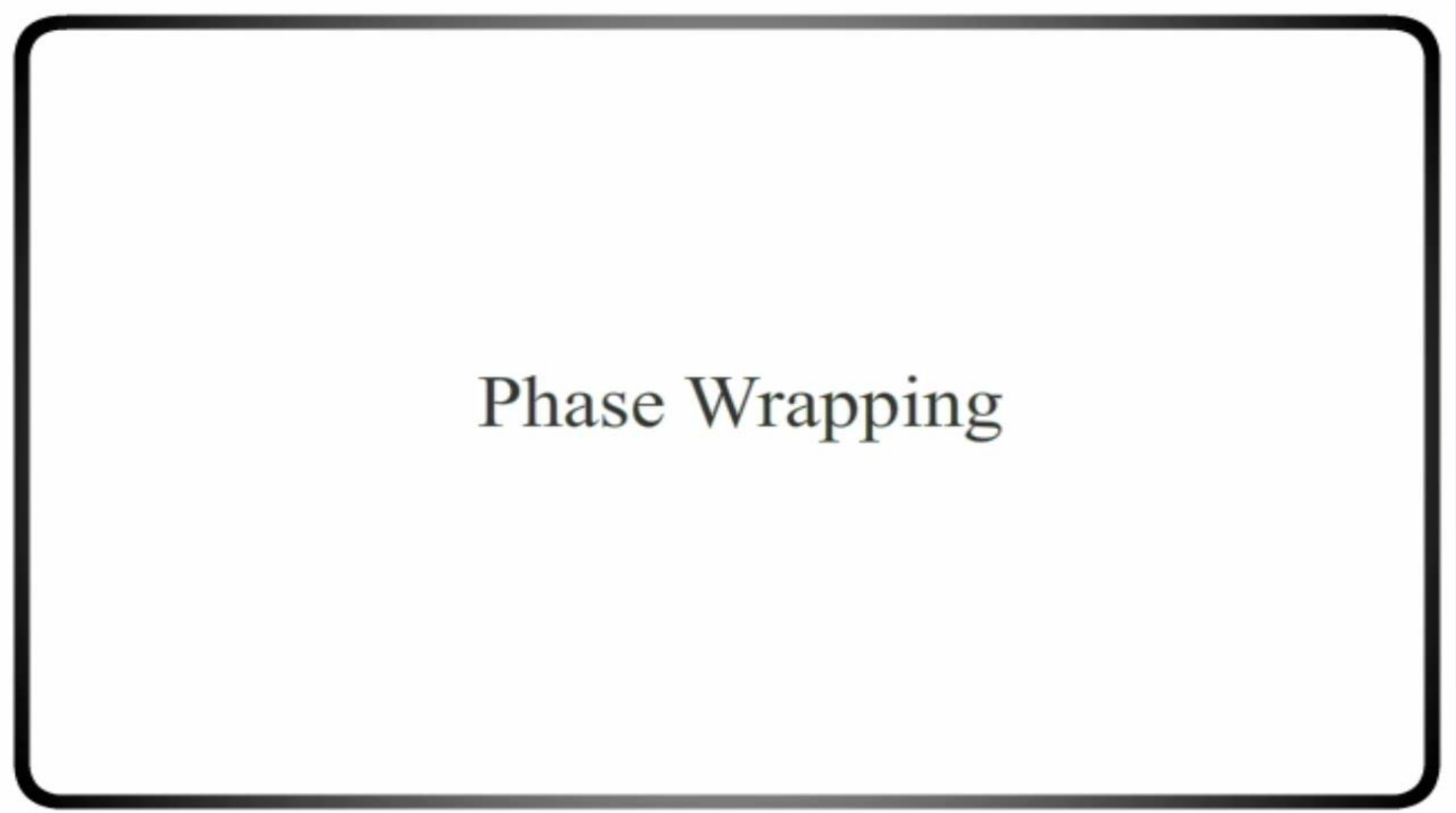
$$\Delta n = \frac{diopter}{C} = \frac{1.6\text{dpt}}{396.03\text{dpt}} = 0.00404$$

Rationale for Phase Wrapping

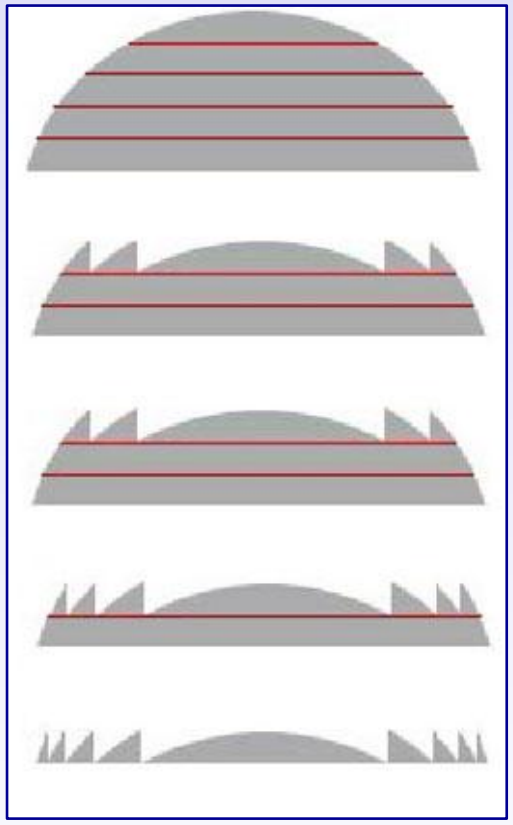
- In a traditional convex lens one would be limited to a height of 200um in order to adjust the optical power of the IOL.
- The power for a 6mm lens with a height of 200um would be 0.44dpt (Δn = 0.01).
- Phase Wrapping is a process which is used to create a RIS “Lens“ with enhanced diopter change, without increasing the height of the “Lens“.



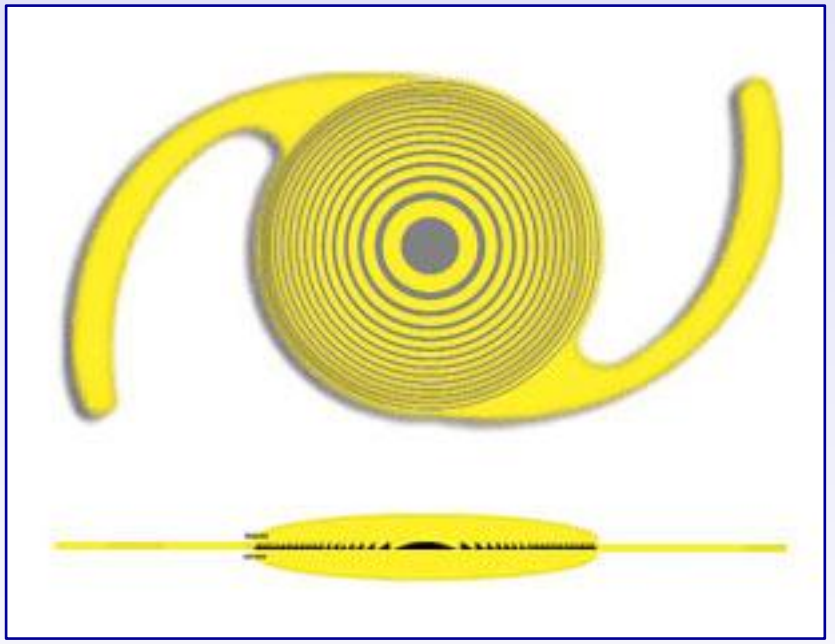
Animation



Phase Wrapping Implementation



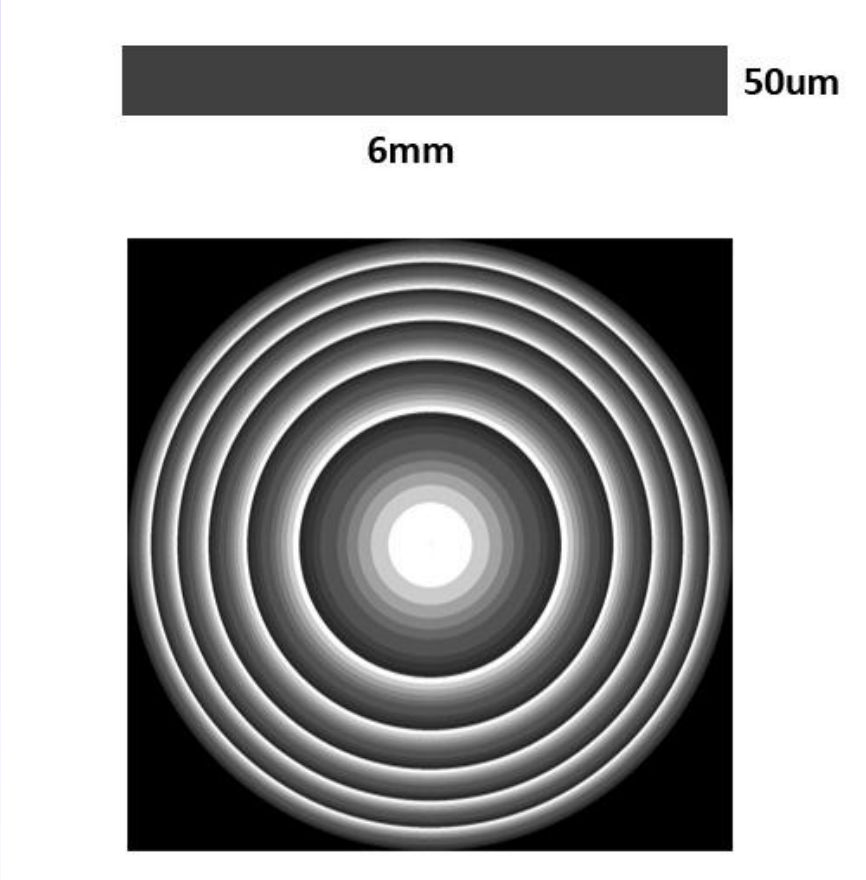
0.5 dpt defocus



1.5 dpt defocus

One zone corresponds to 0.1 diopter

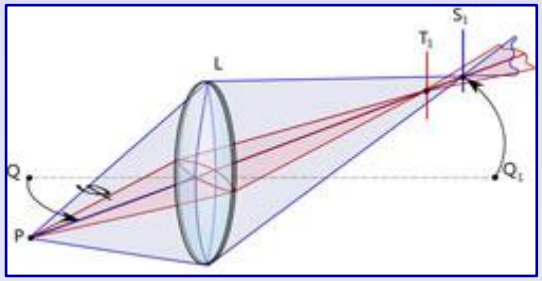
Ultra-Fast Phase-Wrapped 50µm Layer



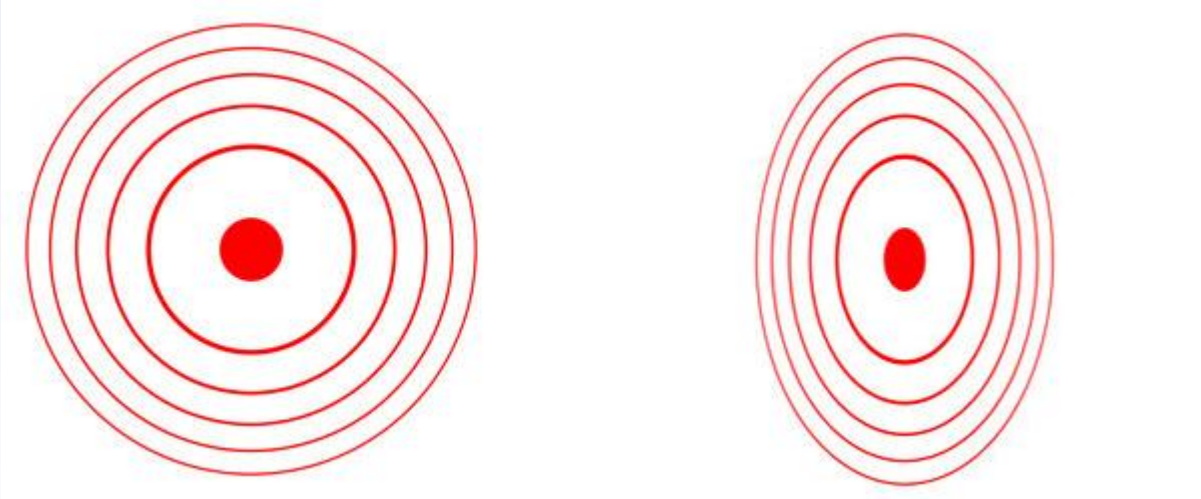
Side-View

The local modulation of the optical pathlength can be accomplished by controlling the laser energy with the acousto-optic modulator (AOM) at a speed of 10 million pixels/sec and with a dynamic range of 100:1.

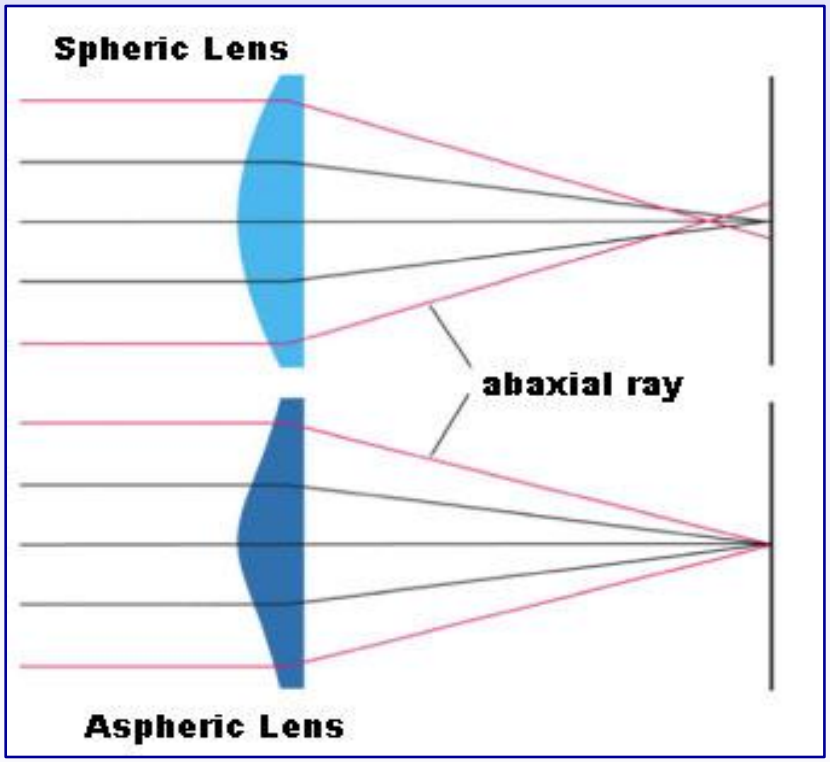
Astigmatism

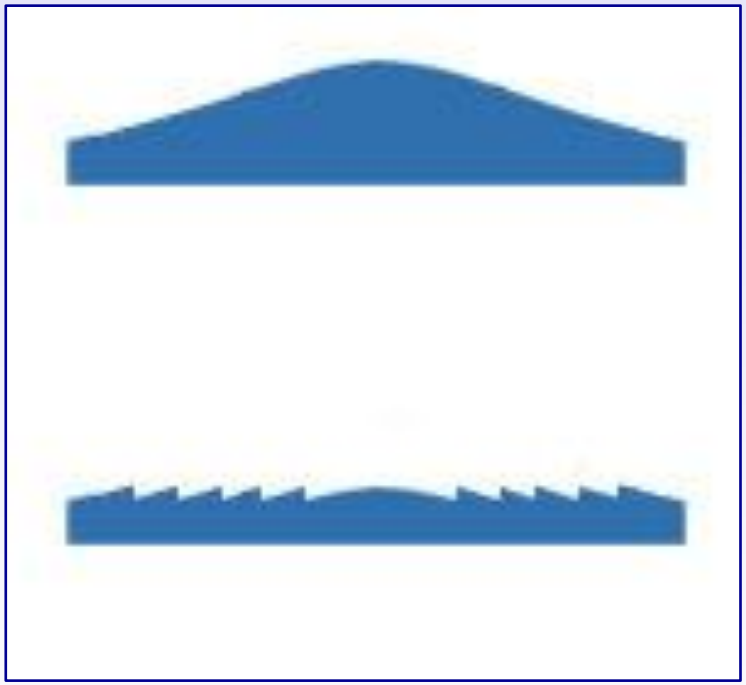


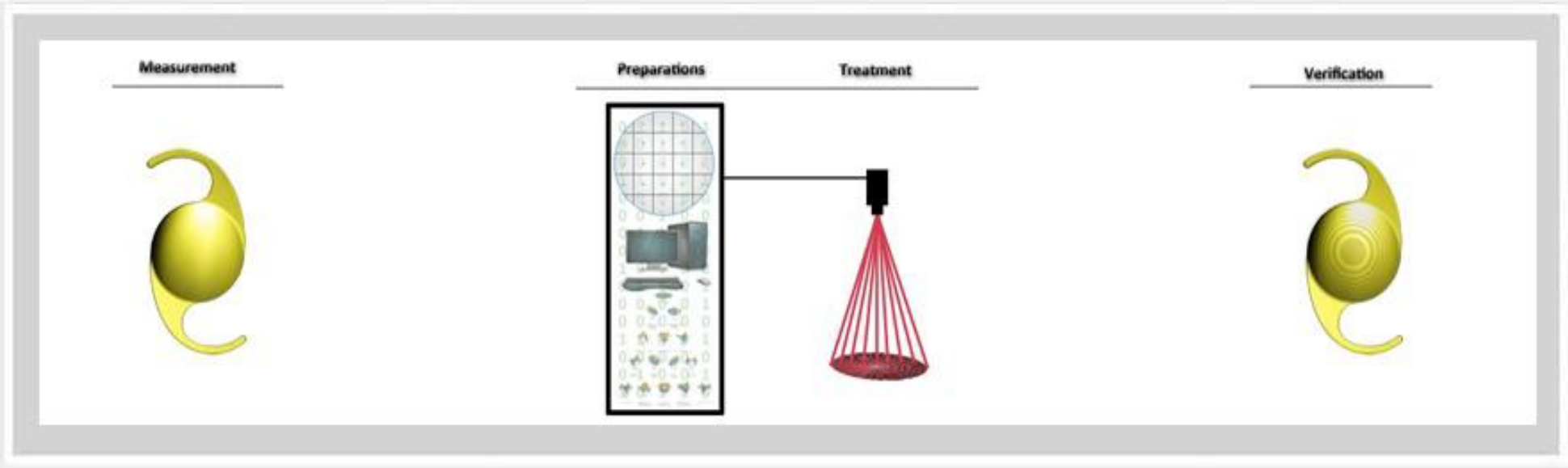
Toric IOL



Aspheric IOL







IOL-Manufacturing Procedure

Left: Measurement, Middle: Preparation,

Treatment, Right: Verification

Future: „Cut-Free Refractive Surgery“

Autofluorescence of Cornea

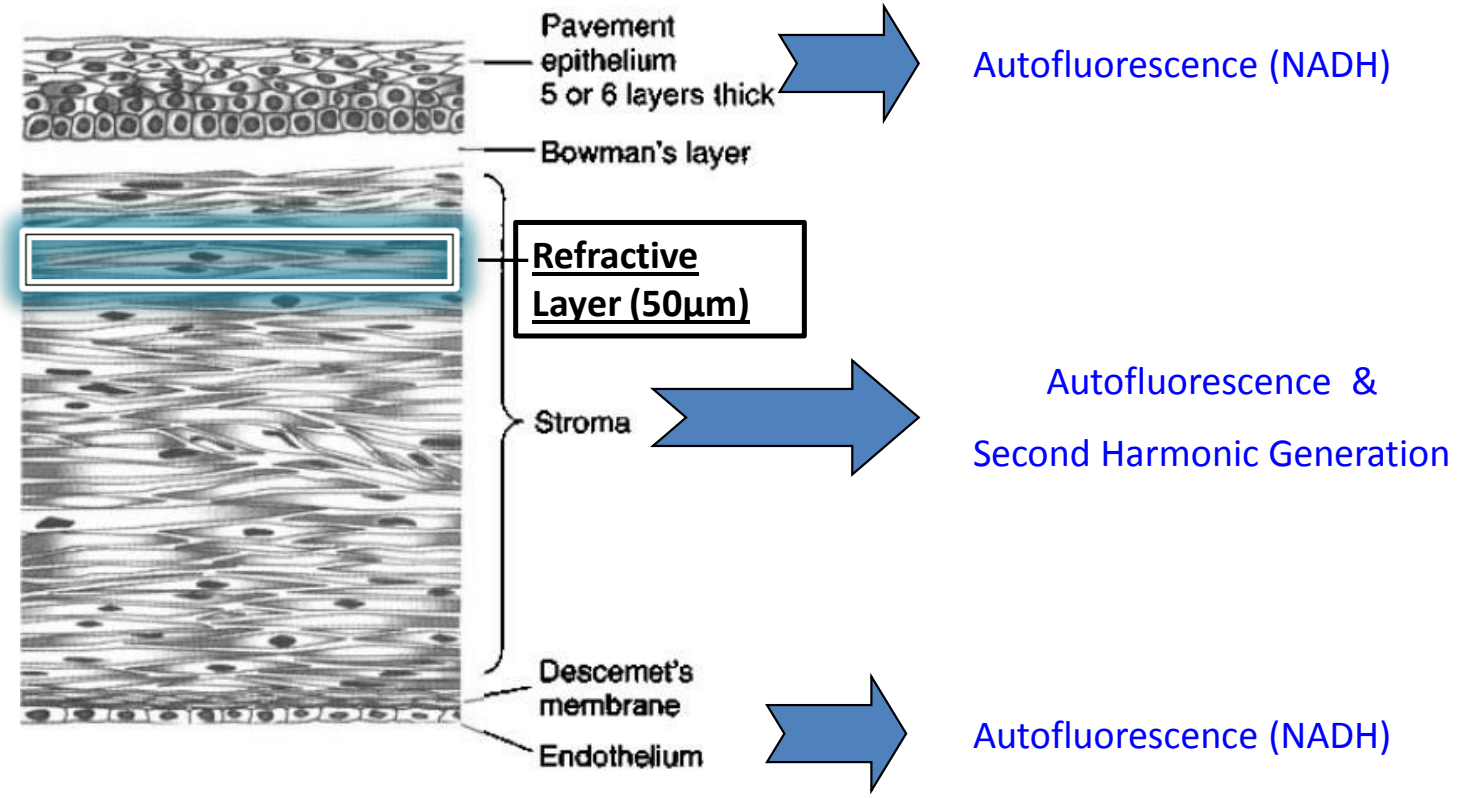


Fig.1 Cornea refractive layer; the positioning of the layer is guided via the autofluorescence image of the cornea, received in the 2-photon excited fluorescence mode(TPEF-imaging).

Summary

- A novel method for in situ modification of customized IOLs has been developed.
- The method could be used to create a customized IOL.
- Refractive Index Shaping (RIS) can be used to adjust the power of an IOL in situ by focused infrared femtosecond laser pulses.
- RIS was successfully performed on Aaren‘s hydrophobic acrylic IOLs.
- Employing phase wrapping techniques, several diopters of refractive change can be accomplished in a thin layer of approximately 50µm thickness.
- Using an acousto-optic modulator (AOM) a total processing time of approximately 20 seconds can be achieved.

Thank you for your attention!