A New Approach to Contact Lens Presbyopia Correction with fs-Laser Refractive Index Change

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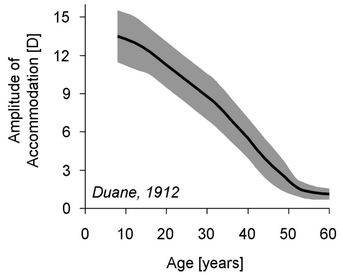
Introduction

The eye's ability to change focus, or accommodate, is lost by the age of 45 years. This age-related loss of accommodation, known as presbyopia, is due the life-long growth and stiffening of the eye's crystalline lens.

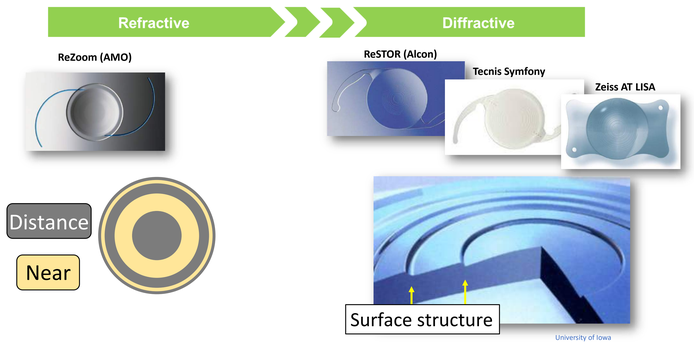


Evolution of presbyopia-correcting intraocular lenses (IOLs) from refractive to diffractive has led to significant benefits in visual quality and spectacle independence.

Alternatively, contact lenses have not benefited from recent advances in multifocal design due to limitations such as requiring smooth front and back surfaces.

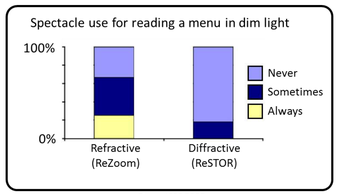
To overcome these limitations, we propose embedding diffractive multifocal wavefronts internally within a contact lens using ultrafast laser technology to create a gradient refractive index lens.

Benefits of Diffractive Multifocals



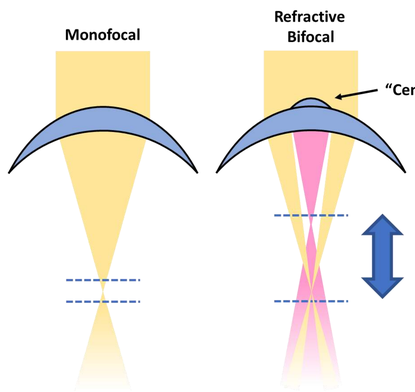
Diffractive multifocal IOLs offer benefits to patients seeking full range of vision:

- **Higher patient satisfaction**
- **Less halos and glare**
- **Higher spectacle independence**

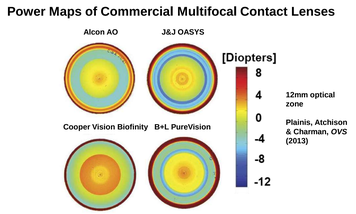


Chang JCRS 2008

Current Contact Lens Presbyopia Correction



Increased Depth of Focus

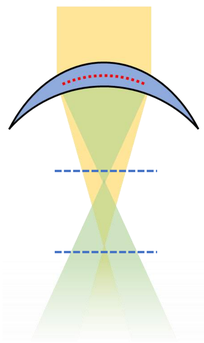


Wavefronts determined by:
- **Surface curvature**
- **Thickness profile**

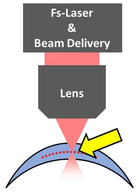
Limitations:
- **Pupil dependent image quality**
- **Decentration**
  - **Blink-induced**
  - **Fitting stability**

Enabling *Internal* Diffractive Wavefronts

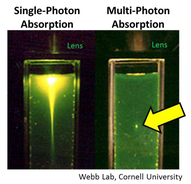
LIRIC: Laser Induced Refractive Index Change



Mechanism of RI Change via fs-laser



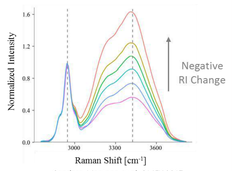
- Highly localized RI change (μm scale)
- Multiphoton process



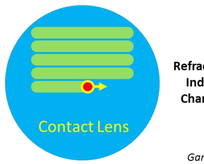
Webb Lab, Cornell University

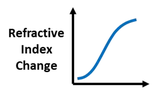
- Decrease in RI
- Increase in $\%H_20$

Raman Spectroscopy



Gandara-Montano et al. OMEX 2017

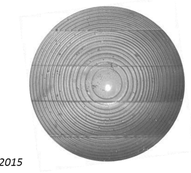




Gandara-Montano et al., OMEX 2015

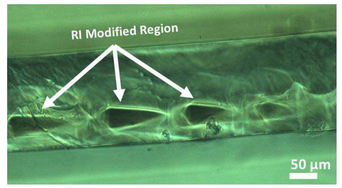
High resolution scanning for controlling refractive index change

Front View



Bright-field imaging

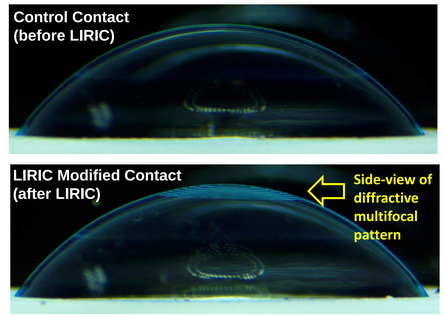
Side View



Phase-Contrast Microscopy

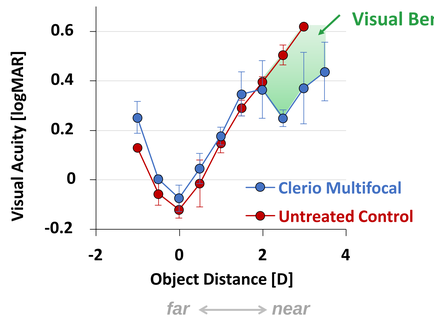
Induced wavefront is embedded within contact lens

Results



Experimental Methods
- LIRIC wavefront:
  - Diffractive bifocal
  - +2.5 D add power
  - Distance-weighted diffraction efficiency (~70/30% far/near)
- Plano hydrogel
- 4mm artificial pupil
- White light
- N = 12 eyes

Significant Visual Benefit



2.5 lines of benefit at near

0.5 line loss of distance acuity

Conclusions

High-quality presbyopia-correcting multifocals are created by embedding the diffractive LIRIC structure internally within the material, avoiding surface perturbations which previously prohibited diffractive contact lenses.

Benefits of LIRIC-diffractive contact lenses include:

- **Next-generation presbyopia-correcting multifocals**
- **Uniform thickness single-vision correction via LIRIC Fresnel lenses**
- **Correction of higher order aberrations, prism, chromatic aberration**

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