Non-ablative ultra-pulsed laser interaction With intraocular lenses For refractive power modification

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NON-ABLATIVE ULTRA-PULSED LASER INTERACTION WITH INTRAOCULAR LENSES FOR REFRACTIVE POWER MODIFICATION

Purpose:

- The aim of this work is to present our experimental efforts on **laser induced refractive power modifications of intraocular lenses (IOLs)**.
- Nondestructive photorefractive alterations of an IOL must be induced by focusing the laser beam at fluence below the damage threshold, while the defocused beam further shining the retina should not overcome the maximum permissible exposure levels (MPE).
- In our work, the relevant physico-chemical background of the focal length alteration of an IOL through refractive index tuning will be outlined.

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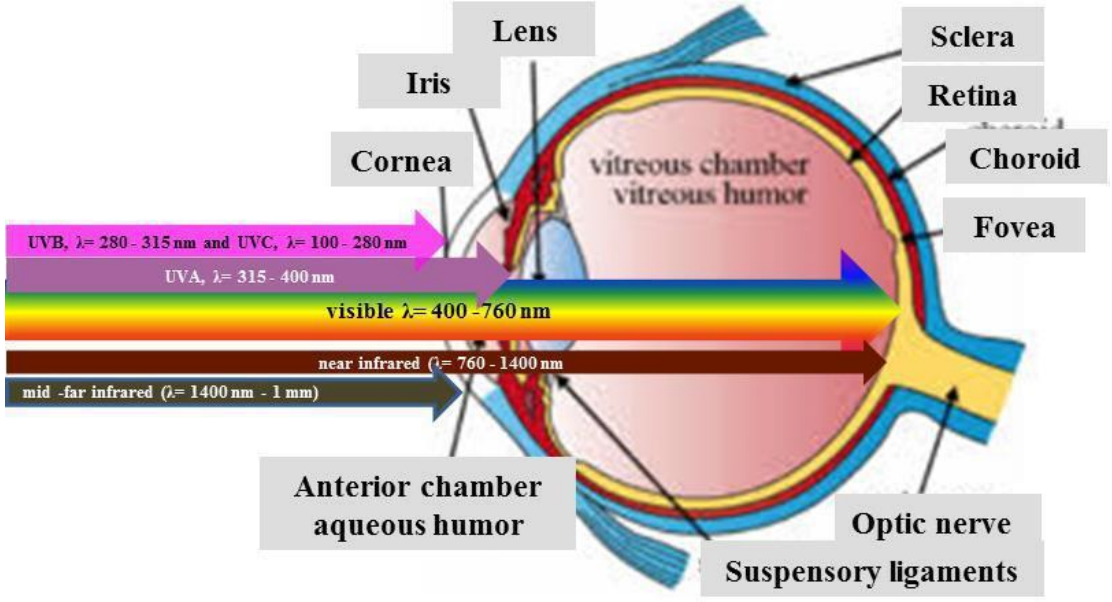
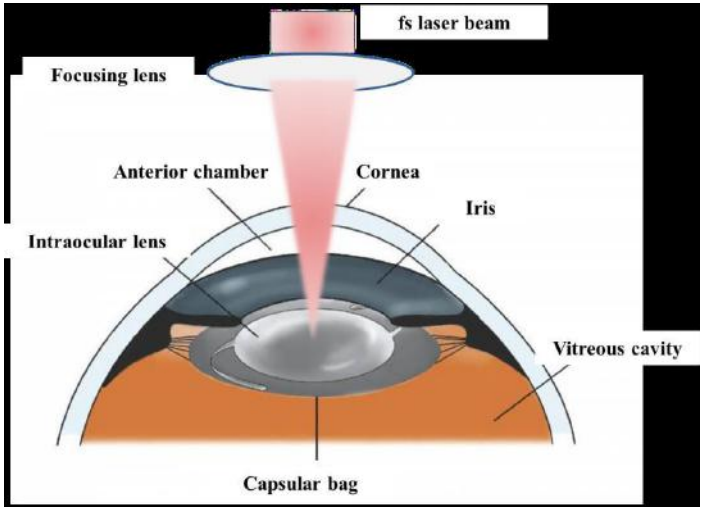
Introductory remarks

- **A typical postoperative complication in cataract surgery is that the refractive power of the implanted IOL is often not sufficient for optimal vision, requiring the patient to use prescription eye wear .**
- **Regarding this problem, an interesting goal is to modify later on and non-invasively the refractive power of an already implanted intraocular lens-IOL, after cataract surgery.**
- **Sahler *et al* recently [2016] reported that the refractive properties of an IOL can be customized after implantation, using a femtosecond laser that alters the hydrophilicity of defined zones within an IOL and thus build a refractive index shaping lens within that zone.**
- **The refractive index is a fundamental physical quantity that characterizes optical materials in various experiments.**
- **The Wayne H. Knox group in the Institute of Optics, University of Rochester, suggested that the laser-induced crosslinking within a hydrophilic material creates an increase in the refractive index.**
- **The Knox group also tested the feasibility of intratissue refractive index shaping (IRIS) in living corneas by using near infrared (800 nm) or blue (400-nm) femtosecond (fs) laser pulses (blue-IRIS).**

Introductory remarks

- **The non-invasive modification of an implanted IOL could be possible by using the appropriate laser light to modify the intraocular implant optical parameters.**





Light transmittance through human eye: **This is directly related to the wavelength of the laser radiation that could be considered for *in situ* interventions.**

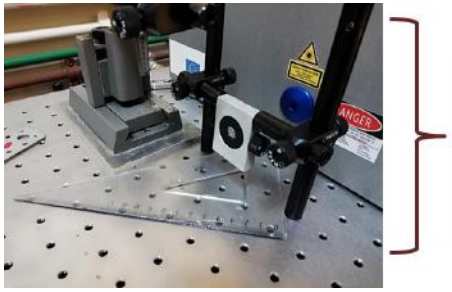
Modification of the refractive index of an implanted intraocular lens by a femtosecond laser.

Materials and methods

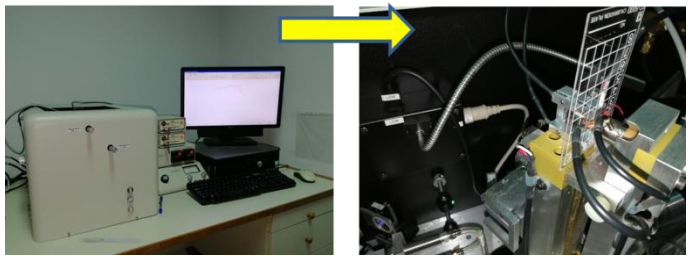
- Laser - IOL interaction experiments were performed in laboratory on commercially available IOLs, as well as on contact lenses and PMMA plates, applying different laser radiation parameters.

- The laser source was a pulsed laser (Ti:Sapphire laser) at λ= 800 nm, pulse width t_p=48 fs, frequency=85 MHz and mean power P= 360 mW.

- The morphology of the ablated IOL and PMMA surface and quantitative measurements of the refractive index were examined at various settings of laser pulses, different focal length and laser fluencies, with the help of (a) SEM IMAGING AND (b) a spectra refractometer (Metricon) and Digital abbe refractometer (Kruss Optronics) in constant temperature.



Experimental set up for the irradiation of IOL's from the fs laser system.

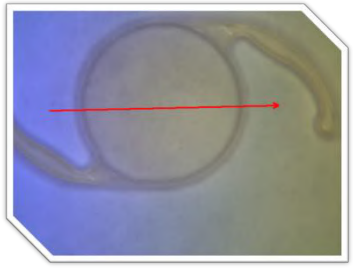


The refractometer and a detail of the set-up, with the PMMA calibration plate.

Materials and methods

- Several methods for index measurement have been proposed, and utilized in the field. Interferometric techniques have also been developed for measuring the small changes in refractive index, among them Optical Coherence Tomography (OCT).

The Thorlabs TELESTO SD-OCT Imaging System.

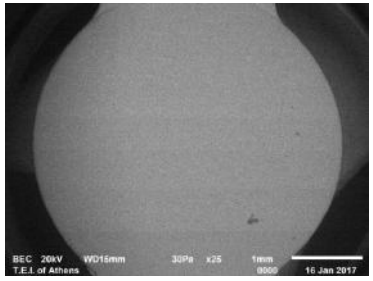


OCT) is a noninvasive imaging technique that records cross sectional images of transparent tissues and polymers.

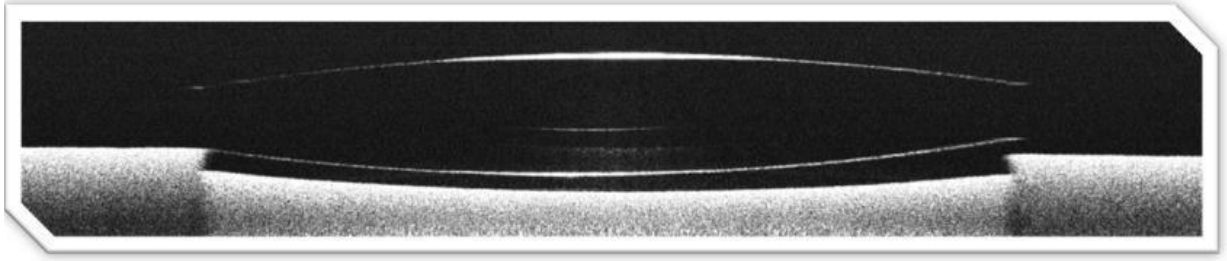
Results

The experimental results of the modification of the refractive power values of intraocular lenses after fs laser irradiation show small differences in the measured refractive index. However, according to literature, about 0.3 to 2.5 diopters correspond to 1% change of refractive indexes.

SEM image of IOL with initial optical power of +16 D, after the irradiation with fs laser (t=20min, d=4mm, P=360mW). There is no evidence for ablation or damage of the IOL.



Optical Coherence Tomography imaging. The IOL was first irradiated with the fs laser system. The two bright lines denote the top and bottom boundaries of the material's layer.



Conclusions and perspectives

- **Our first preliminary results indicate a small modification of the refractive index of the polymeric ocular lenses and PMMA plates.**
- **We hypothesize that the laser interaction with IOLs depends on both optical and physico-chemical material properties.**
- **The exact mechanism for photo-induced modification of refractivity must be further elucidated, before any attempt to translate this research into in vivo and, furthermore, to clinical applications. Moreover, the hypothesis that the underlying mechanism is a cross-linking procedure involving a photo-induced photochemical process and the possible role of hydrophilicity must be further studied.**
- **Additionally, thermal effect can also alter the refractive index due to the local heating of IOL by the near infrared laser beam.**
- ***It seems that postoperative, noninvasive IOL power adjustment can be obtained.***

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Thank you for your attention