Measurement of the thickness of the corneal tear-film using a Twyman-Green interferometer

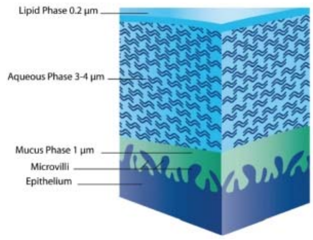
Varis Karitans[1], Inta Silina[2], Juris Lukjanovs[2], Gunta Krumina[2]

[1]*Department of Ferroelectrics, Institute of Solid State Physics, University of Latvia, Kengaraga street 8, Riga, Latvia LV-1063*

[2]*Department of Optometry and Vision Science, Faculty of Physics and Mathematics, University of Latvia, Kengaraga street 8, Riga, Latvia, LV-1063*

Introduction

- In some way a human eye tear-film can be seen as a thin-film.
- Essentially, it is a multi-layered structure.



http://www.clspectrum.com/articleviewer.aspx?articleID=104177

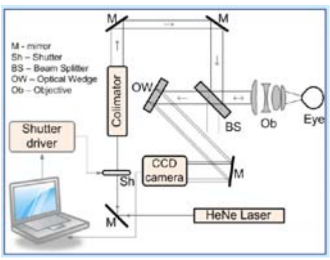
Methods of estimating tear-film quality and thickness

- The break-up time (BUT) test.
- Schirmer's test.
- Scheimpflug imaging.
- The optical coherence tomography (OCT).
- Projection of a grid on the surface of an eye.
- Reflectometry;
- Interferometry.

Interferometry

- Interferometry methods have gained more and more attention in assessment of the quality of the tear-film.
- These methods have been used both to characterize the break-up dynamics and thickness of the tear-film.

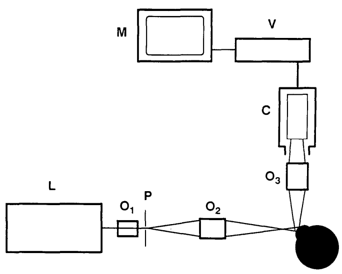
Tear-film dynamics

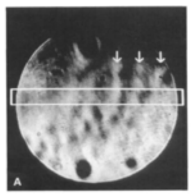


Tomasz J. Licznerski, Henryk T. Kasprzak, and Waldemar Kowalik
Technical University of Wroclaw, Institute of Physics, Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland
(Paper CDO-010 received Feb. 5, 1998; revised manuscript received Nov. 23, 1998; accepted for publication Nov. 24, 1998.)

APPLICATION OF TWYMAN–GREEN INTERFEROMETER FOR EVALUATION OF *IN VIVO* BREAKUP CHARACTERISTIC OF THE HUMAN TEAR FILM

Tear-film thickness

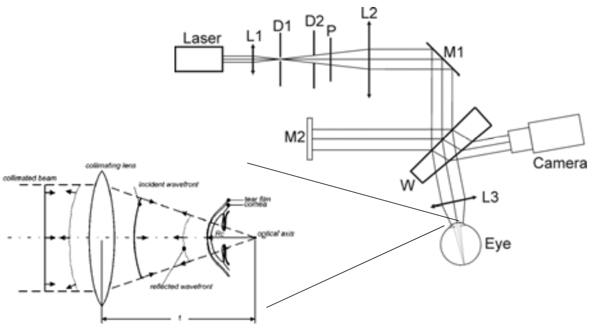




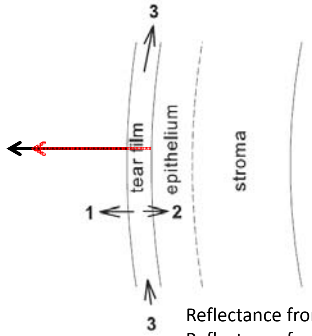
Study of Precorneal Tear Film Thickness and Structure by Interferometry and Confocal Microscopy

Jeremy I. Prydal and Fergus W. Campbell

The optical setup



Creation of interference pattern

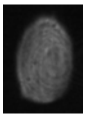
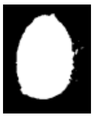


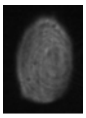
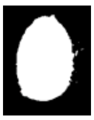
Refractive indices:
air – 1.0000
tear-film – 1.3370
cornea – 1.3771

Reflectance from the first surface R = 2.07 %
Reflectance from the second surface R = 0.022 %

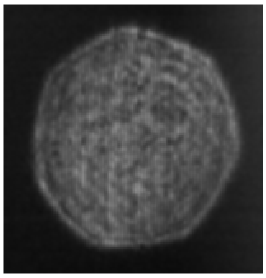
Image processing

- The camera is controlled by MaxIm DL 5.
- The images are processed in Matlab.


Thresholding →

Multiplication →

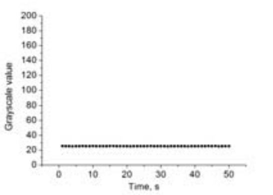
Multiplication →

X

→ Ratio 'sum of grayscale pixels/sum of logical pixels' is the average grayscale value.

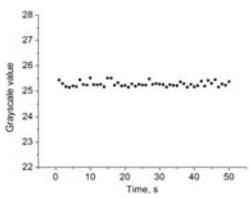
Interference from calibration ball



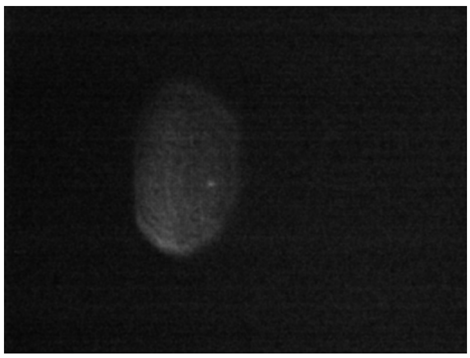
According to manufacturer's specifications the surface roughness equals 0.1 μm.

Time-varying intensity of the calibration ball

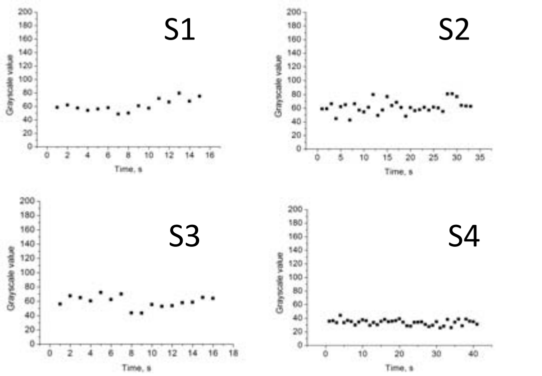




Tear-film dynamics



Time-varying intensity of the tear-film



Fitting function

$E_1 = E_{01}\cdot\sin(\omega\cdot t)$

$E_2 = E_{02}\cdot\sin(\omega\cdot t+\varphi)$

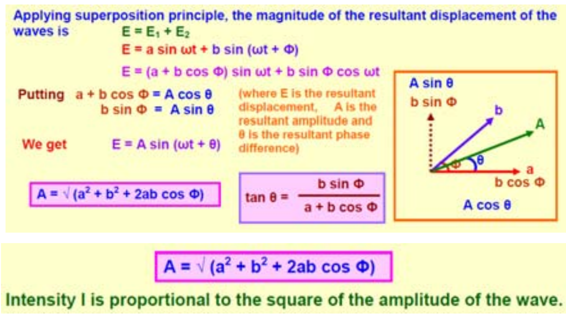
As the beams are coherent

$E = E_1 + E_2 = E_{01}\cdot\sin(\omega\cdot t) + E_{02}\cdot\sin(\omega\cdot t+\varphi)$

The optical path length difference

$\varphi = \frac{4\cdot\pi\cdot n_t\cdot d_t}{\lambda} = \frac{4\cdot\pi\cdot n_t\cdot(A\cdot e^{-\frac{t}{\tau}}+B)}{\lambda}$, where n_t and d_t are the tear-film refractive index and thickness, respectively, A and B – constants, λ - wavelength.

Fitting function



Fitting function

- E =

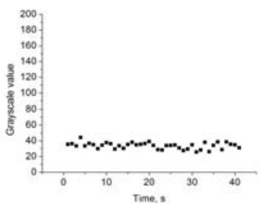
$0.144\cdot E_0\cdot\sin(\omega\cdot t) + 0.0108\cdot E_0\cdot\sin(\omega\cdot t + \frac{4\cdot\pi\cdot n_t\cdot(A\cdot e^{-\frac{t}{\tau}}+B)}{\lambda})$

$I \sim E^2$

$I \sim I_0\cdot(0.02085264 + 0.0031104\cdot\cos(\frac{4\cdot\pi\cdot n_t\cdot(A\cdot e^{-\frac{t}{\tau}}+B)}{\lambda}))$

Calculating the thickness

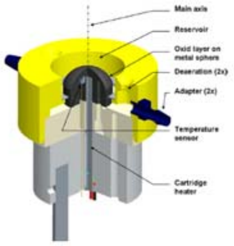
- One period equals $\lambda = 0.6328\ \mu m$.
- Thickness *d* equals:
- d = (n+residual phase/2·π) ·λ



Future plans

- In future we plan to develop a model eye to simulate behaviour of a tear-film.
- We also plan to compare various artificial tears and their thickness and stability.
- Our goal is to make this method useful for determination of the dry-eye syndrome.

A model eye for the tear-film simulation



Stefan Arnold[1,2,*], Holger Bruenner[1], Achim Langenbucher[2,3]

Simultaneous examination of tear film break-up and the lipid layer of the human eye: A novel model eye for time course simulation of physiologic tear film behavior (Part 2)

Conclusions

- The Twyman-Green interferometer can be used to detect variations in light intensity resulting from interference from both surfaces of the tear-film.
- The method is simple and requires no special calibration. In addition, it is rather insensitive to lateral eye movements. Alignment is extremely difficult and it is sensitive to longitudinal movements.
- The method may be useful for detecting the dry-eye syndrome.

Thank You!

The study is supported by the ESF project 2013/0021/1DP/1.1.1.2.0/13/APIA/VIAA/001

IEGULDĪJUMS TAVĀ NĀKOTNĒ