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RESEARCH ARTICLE

Pateras E.S, The *Experiment*, *2014, Vol.23 (2)1577-1584*

COMPARISON BETWEEN AN INTEREFROMETRIC TECHNIQUE AND AN AUTO-REFRACTOMETER FOR DIOPTRIC AND PRISMATIC POWER MEASUREMENT OF OPHTHALMIC LENSES

ASBTRACT

Objective Accurately evaluate and measure the dioptric and prism power of ophthalmic lenses with an interferometric technique and correlate the results with those taken from automated focimetry.

Method and materials Testing of trial ophthalmic lenses, spherical and cylindrical, was carried out using an interferometric technique in order to estimate the dioptric and prismatic power of these lenses. The ophthalmic lenses were measured with a laser light, using a Twyman Green interferometer, and interference patterns were acquired and processed, obtaining the dioptric and prismatic power of these lenses. Comparison of the interferometric technique results was conducted with those taken from an Auto-focimeter (TOMEY TL-100) in order to check if the two techniques of measurement are interchangeable, and statistical analysis was carried out for both types of measurements.

Results The two methods Auto-focimetery and Interferometry (Twyman Green) are correlated. From the statistics of the comparison of the two methods the results were a) the Pearson ρ (precision) correlation coefficient showed that there is a high statistical significant correlation between the two methods (r = 0,9992 - P<0,0001 having a 95% confidence interval for r = 0,9964 to 0,9981), b) also the Correlation coefficient r showed that there is a high statistical significant correlation between the two methods r = 0,9992 - P<0,0001 having a 95% confidence interval for r = 0,9987 to 0,9996) and c) the Spearman's coefficient of rank correlation (rho) showed that there is a high statistical significant correlation between the two methods r = 0,998 P<0,0001 having a 95% confidence interval for r = 0,997 to 0,999).

Conclusions A method for measuring the dioptric and prismatic power of ophthalmic lenses based on interferometry, and more specific a Twyman-Green interferometer was proven to be as accurate as Auto-focimetery. The fringe patterns were photographed and then the power of the wave front produced due to the insertion in the set-up of the trial ophthalmic lens was measured. This was equal to the power of the trial lens used to measured. The fringes were tested compared to the plano reference wave front produced when the system did not have any lens inserted.

Key words: interferometry, Twyman-Green, ophthalmic lenses, power.

INTRODUCTION

A technique based on interferometry[1-10] and its validation is presented for measuring the total power of single vision trial spherical and cylindrical lenses. A Twyman-Green[11-16] interferometer was preferred, which provided a reference wave front, which was plane. The principal concept was to use a simple low cost easy to operate with the least complexion in its set-up interferometer in order to get accurate measurements on the power of ophthalmic lenses. Although the Newton interferometer would be the first choice from the literature it was understood that only one of the surface of the lenses would be measured and not the whole lens. Also this type is a contact interferometer.

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METHOD AND MATERIALS

The experimental device was a Twyman-Green interferometer in order to get fringe patterns of optical components, like prisms, spherical and cylindrical lenses. From the interferograms and their interpretation the power of the lenses tested could derive. **Figure 1.** is a schematic representation of the experimental set up for such a purpose. The Twyman-Green interferometer used in order to measure lenses is actually like the Michelson only a lens +100 mm is inserted into the system in front of the laser at a distance of 10cm at the first principal focus of the lens in order to make the initial laser beam a plane wave front (parallel rays) which would be the reference wave front for comparison with the one produced by any lens element inserted into the system. The laser was a He-Neon laser (red) having a transmitting wavelength of 632, 8 x 10^{-6} mm and with a beam diameter of 0.8 mm.

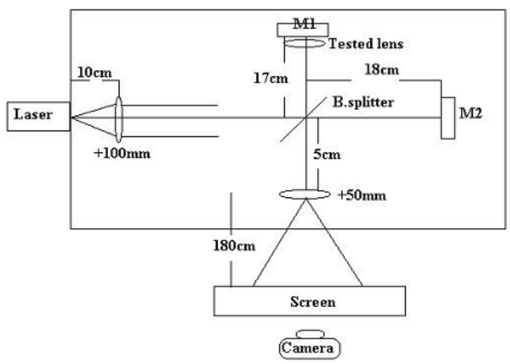

Figure 1. Schematic diagram of the experimental device constructed in order to measure ophthalmic lenses with interferometry. It is a modified Michelson version with a collimating lens +100 mm placed in front of the laser at a distance equal to its first focal point in order to produce a plane initial wave front. Also the camera was placed in alignment with the screen where the fringes were projected.

Figure 2. It is an actual photo of the lab and the modified set-up of the interferometric device (Twyman-Green interferometer).

The set up consisted of, a collimated lens +100 mm, which was placed in front of the laser at a distance equal to its first focal length. This produced the initial "reference wave front" which was plane. A beam-splitter (50/50) was placed oriented at 45° to the laser beam direction in order to divide the initial laser beam into two other components one reflected and the other transmitted. The angle of the splitter related to the laser beam propagation and to the two mirrors of the system is very important. Flat mirrors (one fixed M_2 and the other movable M_1 in terms of three screws for directional movements) were used. The mirrors have a diameter of 35 mm, which is the same as the diameter of the trial tested lenses. This set up produced better optics with less aberration affecting the system.

A camera was placed exactly behind the semi-transparent screen at 0°angle. The exposure time, due to the direct alignment of the film with the fringe pattern (the camera is set 1 m away from the transparent grid), was quicker (better photographs taken by setting the camera with a speed 125 and the diaphragm set at 2). The use of a granite table two tones of weight was necessary in order to reduce the interfering of vibrations on the device and on the fringe patterns produced. Even the least noise or air current could affect the fringe patterns producing a breathing phenomenon.

Before inserting into the system the trial lenses of known power, in front of mirror M1 prisms of 1.00 D, prism 2.00 D and 3.00 D were placed (from the trial case) on a lens holder in order to assess how the system will react, and if it is possible to measure prismatic lenses. Then optical flats were used (1 mm thickness, 5 mm thickness, 8 mm thickness, 10 mm thickness) in order to assess if the thickness of an optical element is affecting the fringe pattern[17-20]. Then trial lenses were inserted. These trial ophthalmic lenses spherical (-1.00, -2.00, -3.00, -4.00 Ds and +1.00, +2.00, +3.00, +4.00 Ds) and plano-cylindrical (-1.00, -2.00, -3.00 and +1.00, +2.00, +3.00 Dc) were taken from a standard trial ophthalmic lens case Topcon TLS-FD trial lens set.

The fringe patterns were photographed and scanned on to a computer in order to calculate the power of the known prisms and lenses. The following equation[20] was used in order to find the power of the spherical and cylindrical lenses tested

$$x_n^2/R = n\,\lambda \;\Rightarrow x_n = \sqrt{n\,R\,\lambda} \;\Rightarrow R = x_n^2/n\,\lambda$$

where x_n is the distance of the nth dark fringe R is the radius of curvature of the optical element under test n is the number of the dark fringe from the centre of the fringe pattern while λ is the wave length of the light source used ($\lambda = 632{,}8 \times 10^{-6}$ mm).

The prism power was derived by measuring the displacement dx of the centre of the circular fringe pattern from the centre of the grid with the metric scale. At first the displacement of the prism of 1 D was measured. Then a 2 D prismatic power or 3 D prismatic lens was inserted in the metric system and it was found that the displacement was 2x times or 3x times the displacement distance of the 1 prismatic dioptre lens.

RESULTS

Examples of the tested lenses (**Figure 3**) with the Twyman-Green interferometer are given below:

For a spherical trial lens of +1.00 Ds the fringe diameter of the 5^{th} dark fringe was 87 mm so $x_n = 87/2 = 43{,}5$ mm. The magnification used to make the fringe pattern visible was 35x. So the actual fringe size was 43,5/35 = 1,24 mm. By using the equation $\mathbf{R=x_n^2/n\lambda}$ then R = 488,20 mm = 0,488 m^{-1}. $F_{lens} = 1/R = 2{,}048$ Ds. But due to the double pass of the beam from the tested lens the wave front power is doubled (Twyman, 1988). So $F_{real} = 1{,}02$ Ds.

It is obvious that with such an experimenting set-up the results taken were very near to the nominal power of the trial lenses tested. It should be mentioned that only the absolute power could be measured and it is not possible to know if the lens is positive or negative. The lenses in order to check the repeatability of the method were measured 3 times using this system.

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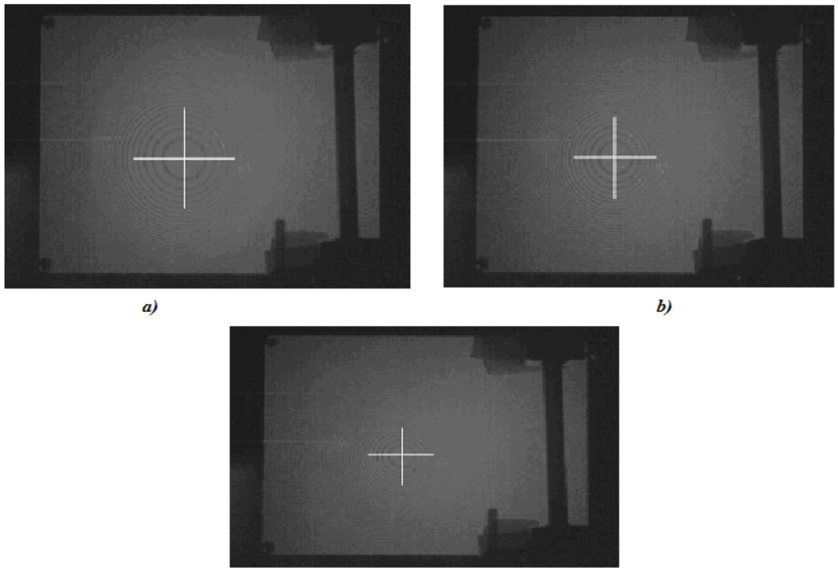
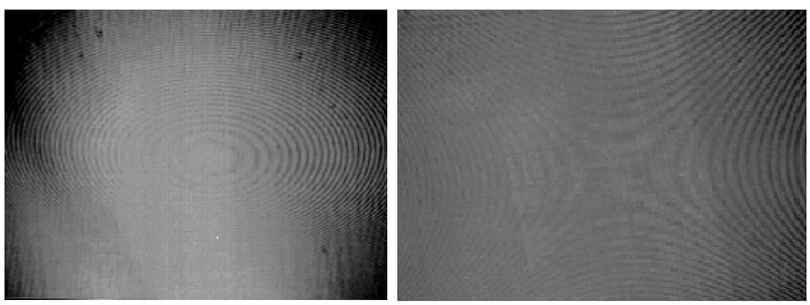


a) b) c)

Figure 3. Fringe patterns of spherical trial lenses tested with a) +1.00 Ds power b) +2.00 Ds power c) +3.00 Ds power.

Figure 4 shows the fringe patterns for plano-cylindrical trial lenses tested.



a) b)

Figure 4. Fringe patterns of plano-cylindrical trial lenses tested with a) - 1.00 Dc power b) + 1.00 Dc power. The axis direction as it is seen is 180°

The statistical analysis of the results for the proposed method compared to Auto-focimeter is given below.

Statistics for the spherical lenses

The sample size for spherical lenses measured with the interferometric technique using Twyman-Green interferometer were 53 lenses between -4.00 to +4.00 Ds.

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Variable	Interferometry
Sample size	53
Lowest value	-4,0100
Highest value	4,2100
Arithmetic mean	0,0285
95% CI for the mean	-0,5453 to 0,6023
Median	0,3700
95% CI for the median	-0,8973 to 0,8478
Variance	4,3332
Standard deviation	2,0816
Standard error of the mean	0,2859
Coefficient of Skewness	0,0496 (P=0,8737)
Coefficient of Kurtosis	-0,3946 (P=0,4264)
Chi-square test for Normal distribution	accept Normality (P=0,6802) (Chi-square=5,705 DF=8)

The sample size for spherical lenses measured with the Auto-focimeter was the same 53 lenses measured with interferometry.

Variable	Autofocimeter
Sample size	53
Lowest value	-3,9400
Highest value	3,9500
Arithmetic mean	-0,0038
95% CI for the mean	-0,5444 to 0,5368
Median	0,2700
95% CI for the median	-0,8173 to 0,7378
Variance	3,8465
Standard deviation	1,9612
Standard error of the mean	0,2694
Coefficient of Skewness	-0,0111 (P=0,9717)
Coefficient of Kurtosis	-0,2940 (P=0,5084)
Chi-square test for Normal distribution	accept Normality (P=0,9748) (Chi-square=1,694 DF=7)

Comparing now the two methods Auto-focimeter and Interferometry

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Variable Y	Autofocimeter	
Variable X	Interferometry	
	Sample 1	Sample 2
Sample size	53	53
Arithmetic mean	-0,0038	0,0285
95% CI for the mean	-0,5444 to 0,5368	-0,5453 to 0,6023
Variance	3,8465	4,3332
Standard deviation	1,9612	2,0816
Standard error of the mean	0,2694	0,2859

Variance ratio test (F-test)

Variance ratio	1,1265
Significance level	P = 0,669

Variable Y	Autofocimeter
Variable X	Interferometry
Sample size	53
Correlation coefficient r	0,9992
Significance level	P<0,0001
95% Confidence interval for r	0,9987 to 0,9996

Variable Y	Autofocimeter
Variable X	Interferometry
Sample size	53
Concordance correlation coefficient	0,9973
95% Confidence interval	0,9964 to 0,9981
Pearson ρ (precision)	0,9992
Bias correction factor C_b (accuracy)	0,9981

Variable Y	Autofocimeter
Variable X	Interferometry
Sample size	53
Spearman's coefficient of rank correlation (rho)	0,998
Significance level	P<0,0001
95% Confidence Interval for rho	0,997 to 0,999

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CONCLUSIONS

A comparison of the two methods (Twyman-Green interferometer and Auto-focimetery) is provided for measuring the power of ophthalmic lenses. More specific a Twyman-Green interferometer was set to measure trial lenses of known power. The fringe patterns were photographed and then the power of the wave front produced due to the insertion in the set-up of the trial ophthalmic lens was measured. This is equal to the power of the trial lens. The fringes were tested compared to the plano reference wave front produced when the system did not have any lens inserted. The results were compared with the results taken by measuring the lenses with an Auto-focimeter.

A statistical analysis of the results comparing the two methods showed that the two measuring techniques **do not different significantly**, for both spherical and cylindrical lenses: a) the Pearson ρ (precision) correlation coefficient showed that there is a high statistical significant correlation between the two methods (r = 0,9992 - P<0,0001 having a 95% confidence interval for r = 0,9964 to 0,9981), b) also the Correlation coefficient r showed that there is a high statistical significant correlation between the two methods r = 0,9992 - P<0,0001 having a 95% confidence interval for r = 0,9987 to 0,9996) and c) the Spearman's coefficient of rank correlation (rho) showed that there is a high statistical significant correlation between the two methods r = 0,998 P<0,0001 having a 95% confidence interval for r = 0,997 to 0,999).

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