Skew-Axis Cylinder Lens Optical System: Novel Method of Clinical Optometry of Astigmatism, Characterization, Theoretical Modelling, and Implementation

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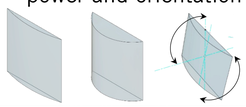
Problem

- Astigmatism – common vision problem – **30% of population**.
- Optometry of astigmatism – suboptimal, low accuracy
- Complex – simultaneously determine 2 parameters (optical power and orientation angle)

Current solutions are:

- Reliant on verbal interaction between patient and practitioner
- Require back and forth iterative discrete lens changes (phoropter)
- Time-consuming
- Expensive ($10,000+)



1. Low optical power
2. High optical power
3. Angle change

Phoropter

Solution

Original apparatus (SACLOS) that relies on novel principles to enable:

- Emphasis on the subjective perception of the patient
- Continuous, rather than discrete, variation of optical parameters
- Direct, intuitive control of optical parameters by the patient
- Simultaneous manipulation of optical parameters using computer interface
- Cheap astigmatism optometry (bill of materials < $100)

Approach

- Optical system of two cylindrical lenses:
  - 2 cylindrical lenses with opposite optical powers, C_0 and - C_0 and independent rotation angles α_1 and α_2
  - A spherical lens of optical power S_l

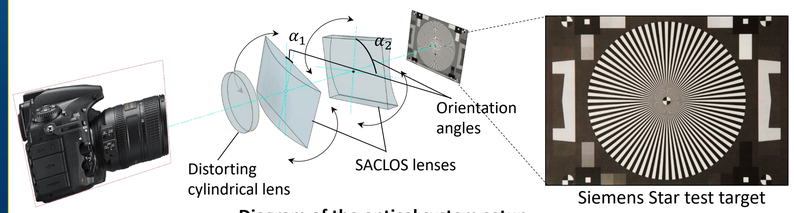
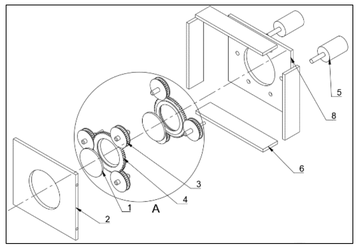


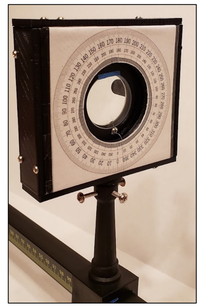
Diagram of the optical system setup

Design and Methodology

Goal: create a Skew-Axis Cylinder Lens Optical System (SACLOS) device to improve the subjective refraction process in the optometry of astigmatism

- Allow a patient to locate the point of the best vision in the two-dimensional space of optical power and orientation angle by using a manual input device (e.g. mouse) in the 2D X-Y space.

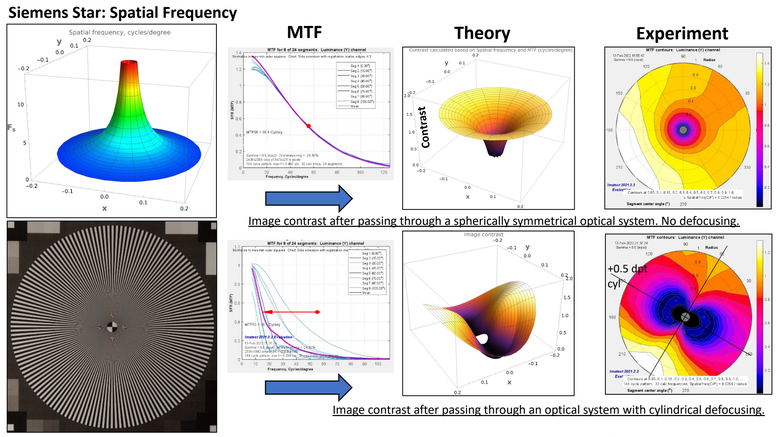




Methodology

- Experiments were conducted using an original specially designed Skew-Axis Cylinder Lens Optical System (SACLOS).
- A distorting cylindrical lens was used to simulate an astigmatic vision defect of a person.
- MTF used as a metric of image sharpness

Results: MTF of the system – Theory vs. Experiment

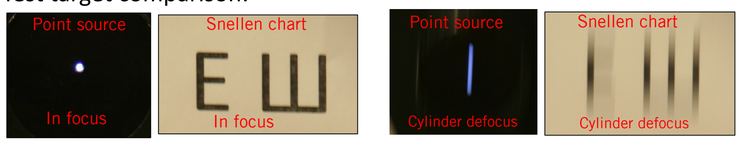


Contrast (cylindrical defocusing): $c(r,\theta) = \frac{1}{\sqrt{\left(\frac{\cos(\theta)}{MTF_{df}(f_S(r))}\right)^2 + \left(\frac{\sin(\theta)}{MTF(f_S(r))}\right)^2}}$

θ = angle of cylinder orientation, r = radius from center

* Derived from geometrical and optical principles

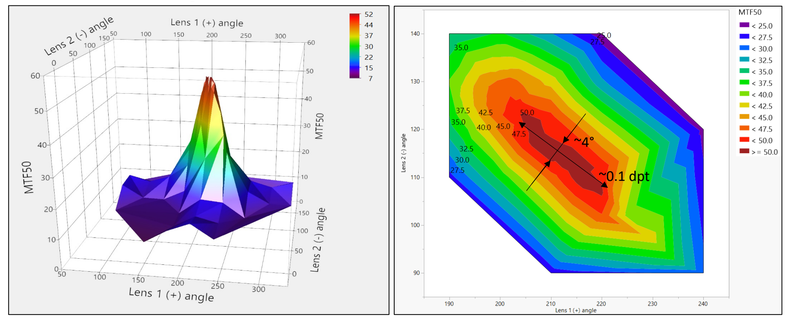
Test target comparison:



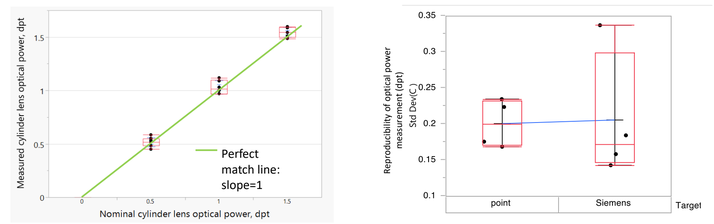
Summary

- A novel method of optometry of astigmatism has been invented
- An original optometric device (SACLOS) has been designed, created, and built from scratch to test and implement the method
- Physical properties of the SACLOS have been studied and characterized
- SACLOS has been demonstrated to accurately measure astigmatic defects
- A theoretical model has been derived and used to optimize the apparatus and procedure
- Experimental data were compared with theoretical predictions
- Novel optometric test target, involving a point light source, has been developed for further optimization of the procedure

Results: Compensation for reference cylindrical lens



Sharpness (MTF50) of the optical system in the presence of a distorting cylindrical lens and SACLOS, as a function of the rotational positions of each SACLOS lens.



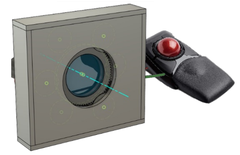
- There is a very good agreement between the measured values and expected values.
- **The error of the measurements is less than a typical error of optometry of astigmatism in a clinical setting (0.25 dpt and 5°).**
  - Confirms that SACLOS is capable of providing the level of accuracy and precision exceeding the typical optometric requirements.

Evolution of subjective optometry of astigmatism

The Past

The Present

The Future



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