Image Quality of the Foldscope

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Abstract

A new optical device, the *foldscope*, captures our attention as an economic alternative to the traditional microscope. Requiring no external power, weighing less than two nickels and small enough to fit in a pocket, the foldscope is advertised to have a magnification of 140 with a resolution of 2 micrometers (able distinguish microscopic features that are 2 thousandths of a millimeter apart). *How well does the foldscope perform in comparison with an ordinary microscope?* The focus of this study is comparing the image qualities of the foldscope and microscope by quantifying the extent of the image distortion (aberration). Specifically, the longitudinal spherical aberration (LSA). Using an image-analyzing software and a camera to capture images produced by the foldscope and microscope of a special viewing sample, we are able to analyze the LSA with the aid of formulas from previous research. The viewing sample is a Ronchi ruling which has pre-measured features that allow its image aberration to be easily identified. Results are pending.

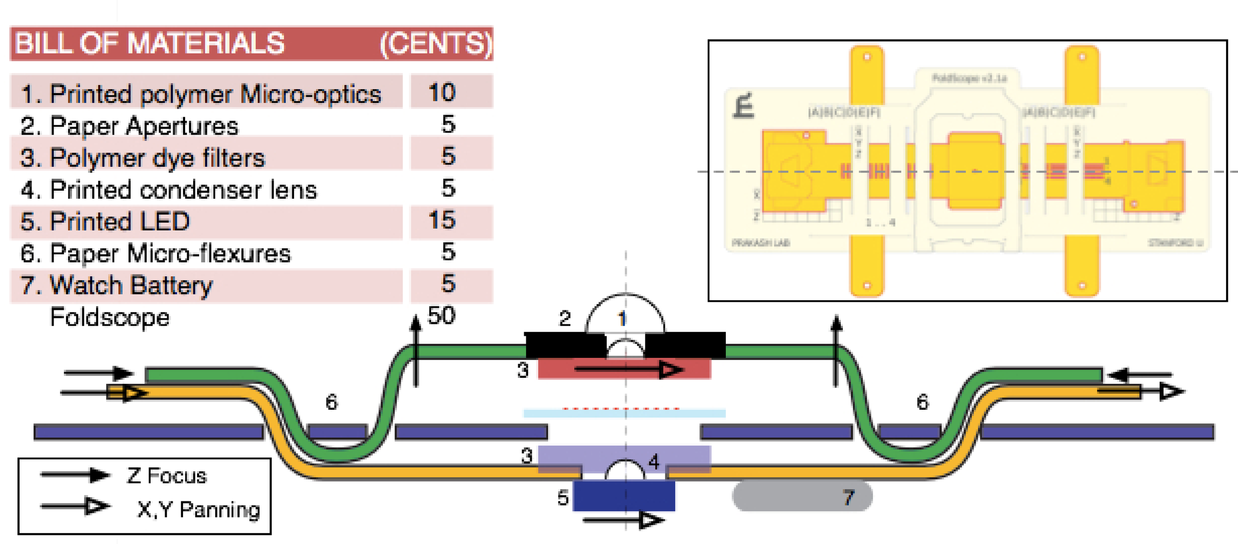

Figure 1. Foldscope design

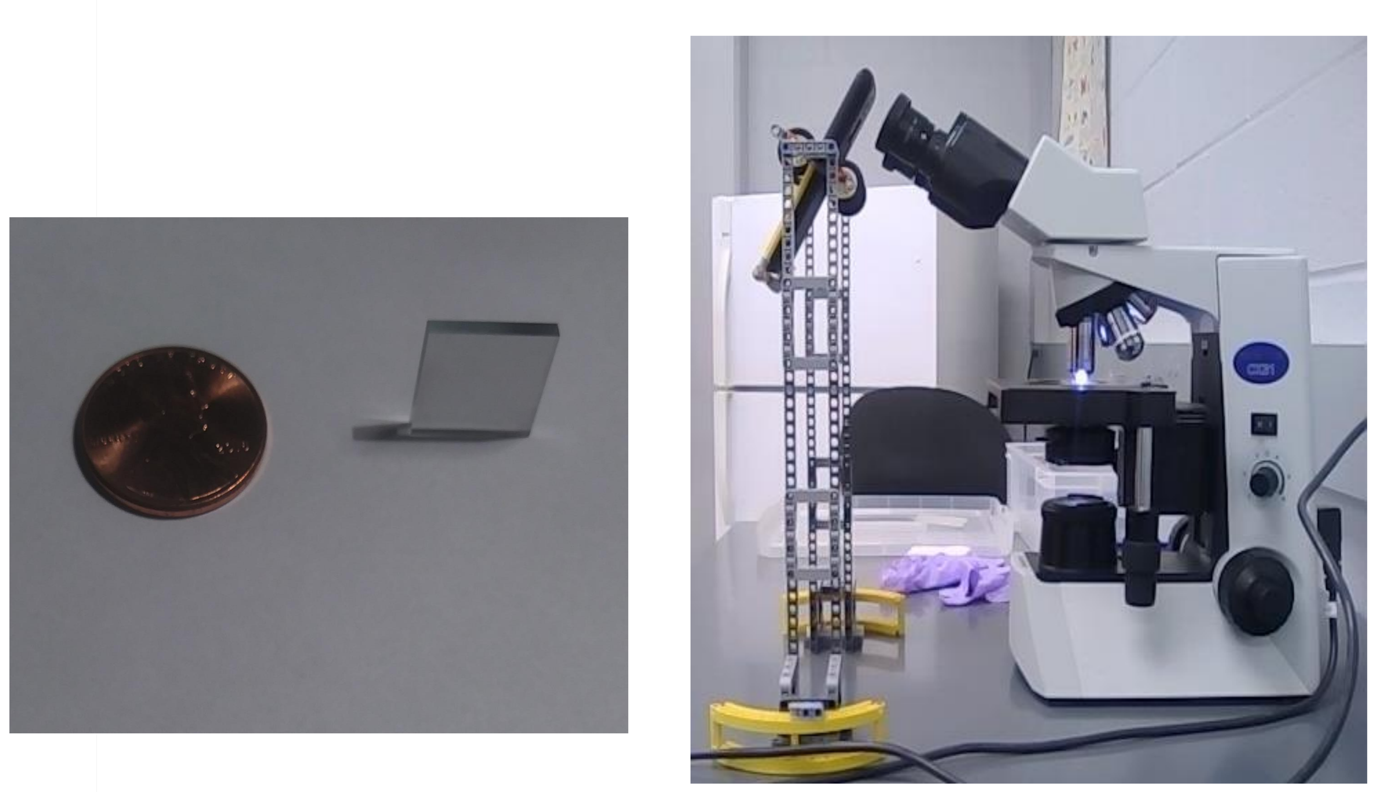

Figure 2. Ronchi ruling (left) and Microscope (right)

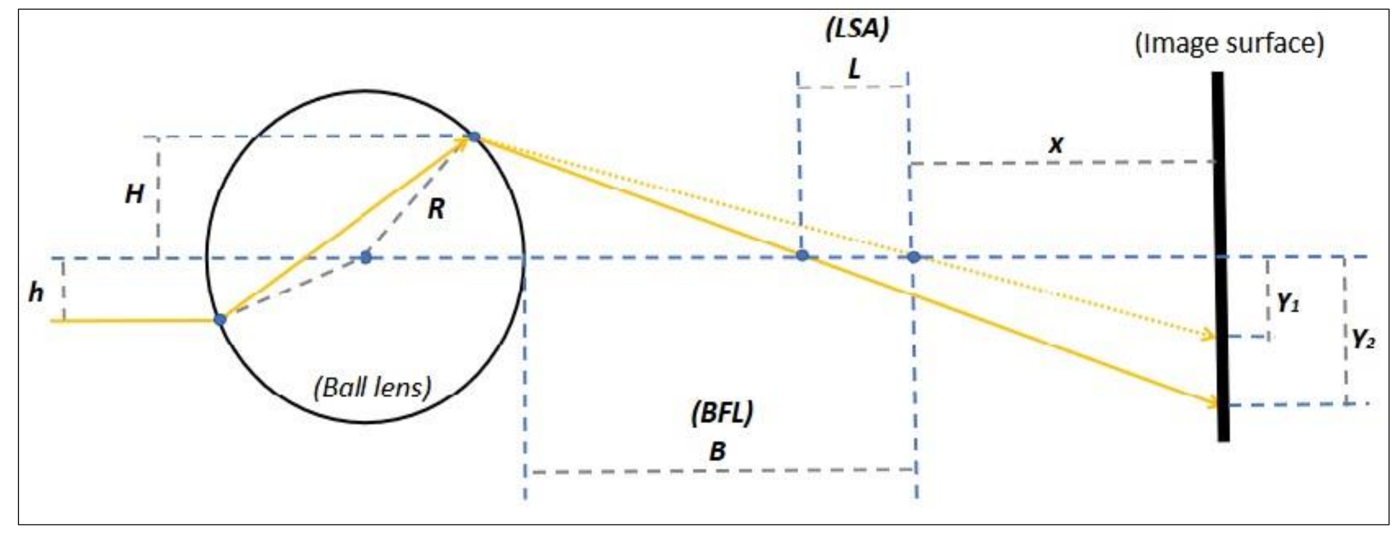

Figure 3. Spherical lens ray tracing

$$L=\frac{nR}{2(n-1)}-\frac{h}{\sin\left[2\left(\sin^{-1}\left(\frac{h}{R}\right)-\sin^{-1}\left(\frac{h}{nR}\right)\right)\right]}$$

Equation 1. (Theoretical relationship)

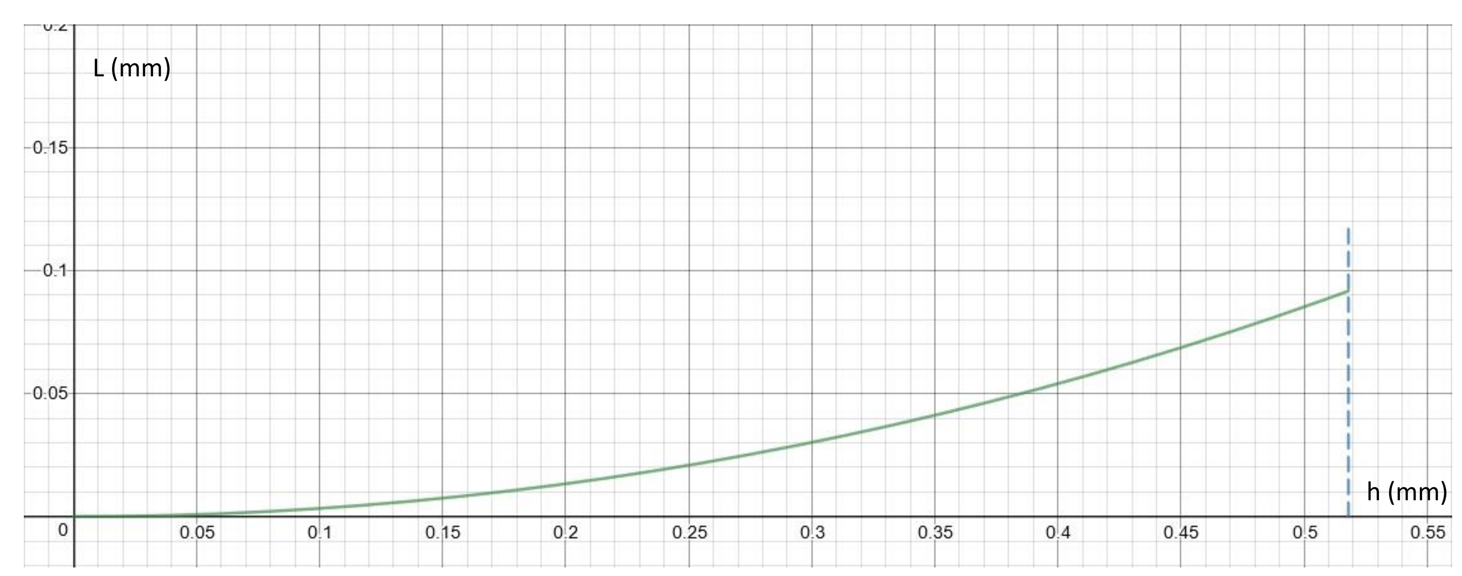

Figure 4. L versus h (Theoretical)

$$L=\left(B+R\left(1-\cos\left[\sin^{-1}\left(\frac{h}{R}\right)-2\sin^{-1}\left(\frac{h}{nR}\right)\right]\right)\right)\cdot\left(1-D^{-1}\right)$$

Equation 2. (Empirical relationship)

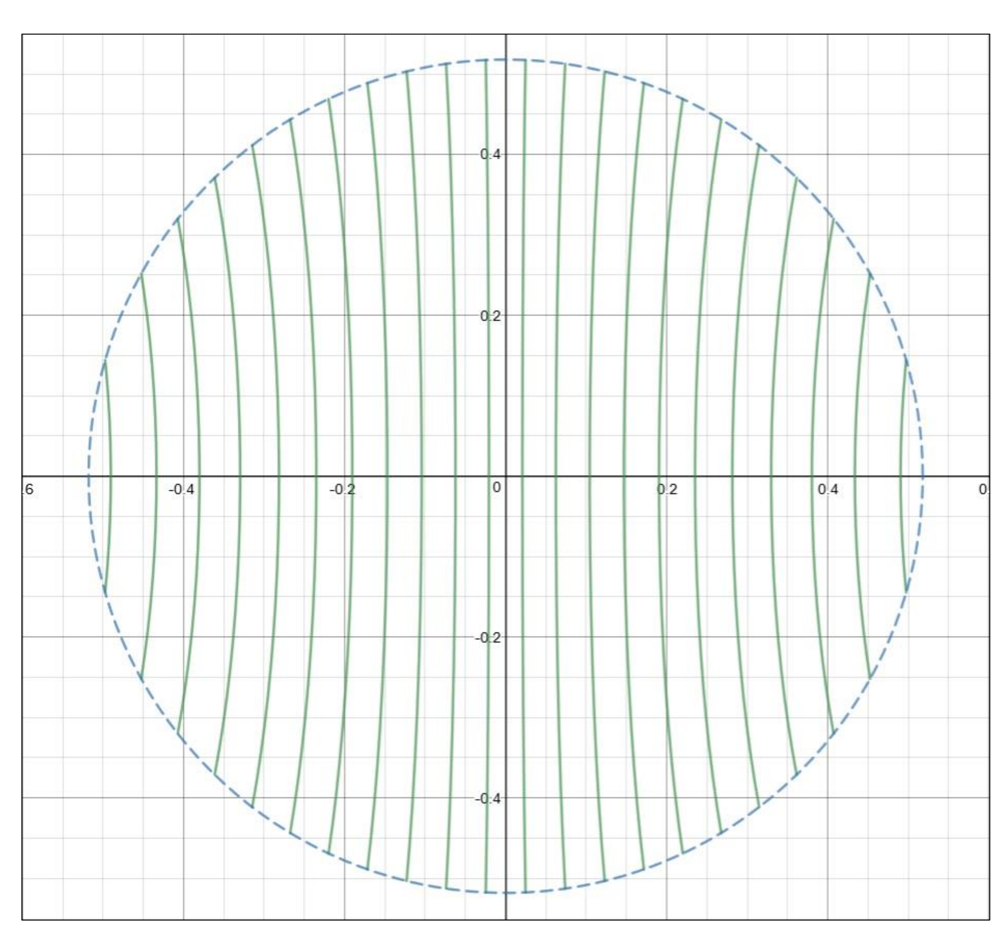

Figure 5. Qualitative theoretical line curvature
Field of view diameter: 0.52mm
Foldscope lens radius: 1.2mm

Methods and Analysis

- A Ronchi ruling line density specification of 100 lines per millimeter was selected to complement the resolution of the foldscope.
- An identical field of view was selected to simplify the comparison of the LSA effects by setting both the foldscope/camera and the microscope/camera overall image magnification to x560.

The LSA can be empirically determined assuming:

- All incident light from the sample is paraxial.
- Overall image deterioration is due to LSA.
- The centered Ronchi ruling slits have an ideal separation unaffected by LSA.

Conclusion

Previous research suggests that lenses with larger radii tend to have less image distortion due to LSA than those with smaller radii. Because the microscope is designed with lenses that have effective surface radii much larger than the radius of the foldscope lens, we expect the microscope to show significantly less image distortion due to LSA.

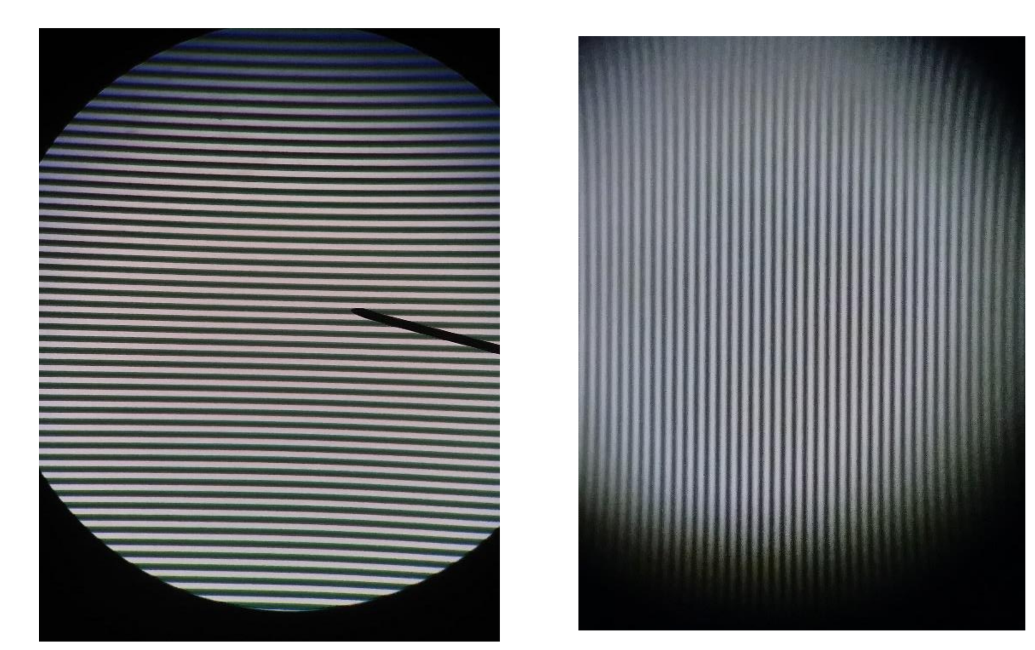

Figure 6. Microscope (left) and Foldscope (right) magnifying Ronchi ruling

References

Cybulski JS, Clements J, Prakash M. (2014). Foldscope: Origami-Based Paper Microscope. PLoS ONE 9(6): e98781. https://doi.org/10.1371/journal.pone.0098781

Hecht, E. (2002). *Optics*. Reading, MA: Addison-Wesley.

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