Doublet and Singlet Lens Characterization, Measurement Device Evaluation

To: Dr. Jennifer Kruschwitz
From: Adam Briggs

10 December 2019

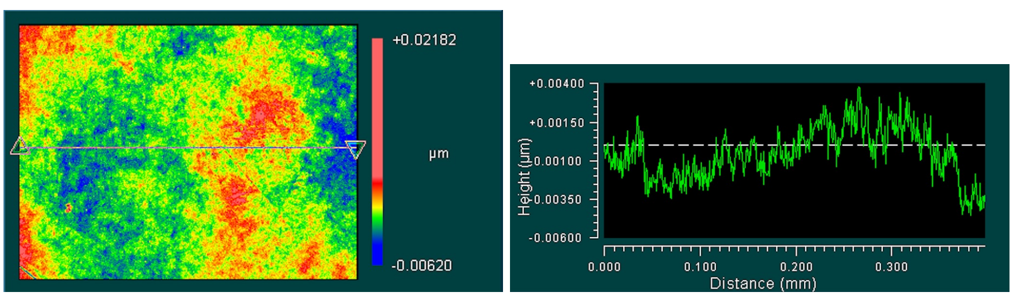
Table of Contents

1 Executive Summary

The Zygo NewView, Zygo VeriFire, Optikos LensCheck, and Konica-Minolta Spectrophotometer were used to measure a positive singlet, a negative singlet, and an achromatic doublet. MTF, EFL, surface roughness, surface figure, radius of curvature, and index of refraction was measured for the positive singlet. Surface roughness, surface figure, radius of curvature, and index of refraction was measured for the negative singlet. MTF and EFL was measured for the achromatic doublet. Additionally, information about the usability, corrected issues, and general advice will be given for each of the measurement devices.

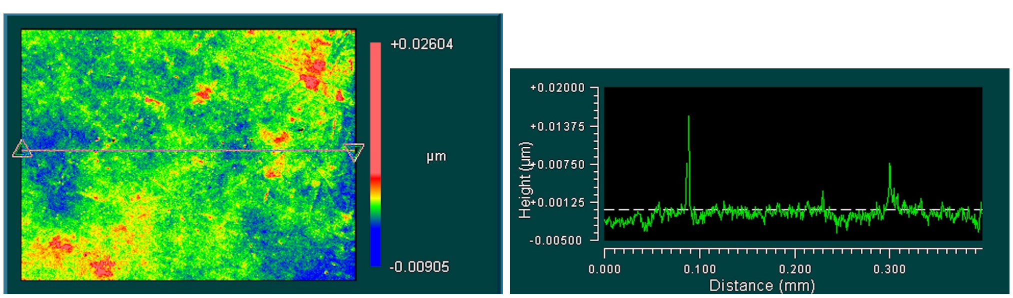
2 Zygo NewView Measurements

The Zygo NewView measures the surface roughness of a lens. In this lab, the surface roughness of the positive and negative lens is measured. The measurements were fairly straightforward to perform. The only difficult part was aligning the negative lens since our element was showing strong signs of wear. Besides that, the NewView was very easy to use. The only advice that should be known is to make very fine adjustments. It is easy to miss the white light fringes and endlessly look for the right location.



3D Plot | Surface Profile

Figure 1: Average PV of the positive lens is 26.47 ± 6.31nm and average RMS of the positive lens is 1.787 ± 0.210nm.

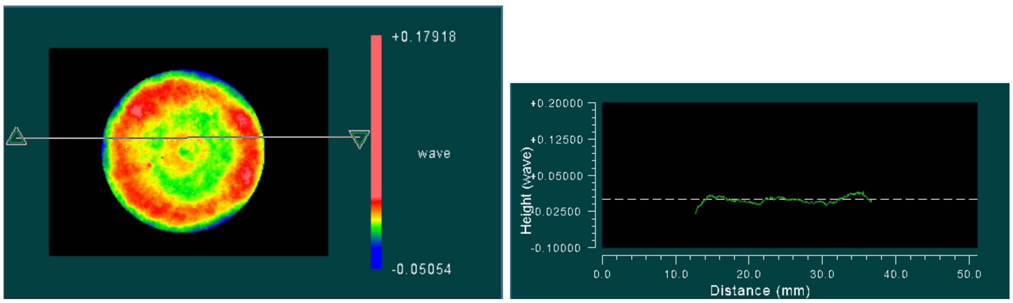


3D Plot | Surface Profile

Figure 2: Average PV of the negative lens is 97.06 ± 78.427nm and average RMS of the positive lens is 2.002 ± 0.202nm.

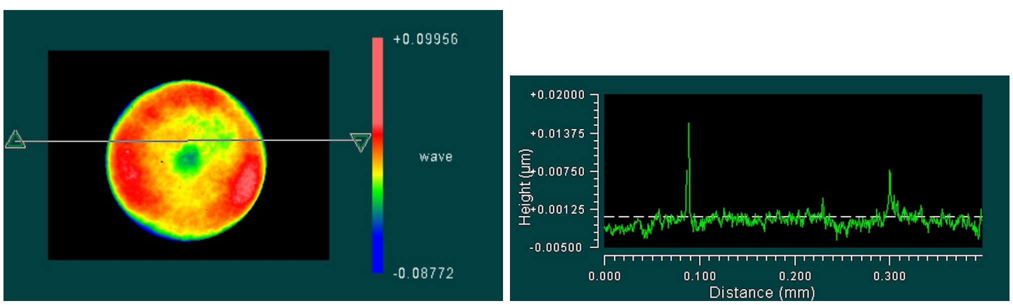
3 Zygo Verifire Measurements

The Zygo VerFire measures the surface figure of an optic. It is a holistic measurement across the clear aperture of the lens. In this lab, surface figure is measured for the positive and negative lens. This device was very easy to use. There were no issues in taking or analyzing any of the measurements. The only advice that should be known is to properly align the optic in the holder before tying to do the fine adjustments.



3D Plot | Surface Profile

Figure 3: Average PV of the positive lens is 0.259 ± 0.02851 waves and average RMS of the positive lens is 0.012 ± 0.0030waves.

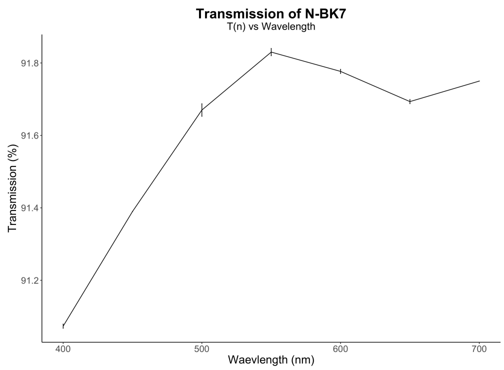


3D Plot | Surface Profile

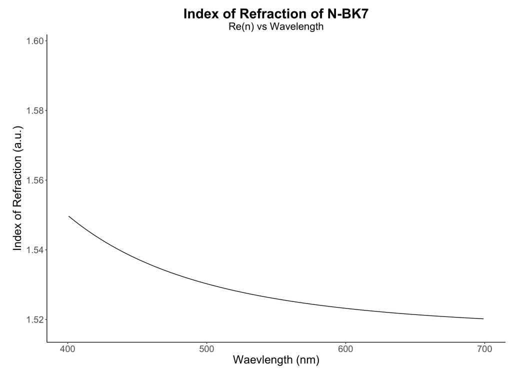
Figure 4: Average PV of the positive lens is 0.207 ± 0.0200nm and average RMS of the positive lens is 0.024 ± 0.0070nm.

4 Konica-Minolta Spectrophotometer Measurements

The Konica-Minolta Spectrophotometer is able to measure the transmission and reflection of different optical materials. The real part of the index of refraction can then be calculated as a function of wavelength. In this section, the transmission of a N-BK7 was taken and $\Re(n)$ was calculated. This process was very easy to perform. It is just clicking the proper items in OptiChar. I would advise future students to pay careful attention to the manual to make sure that everything happens in the right order.



Transmission of N-BK7

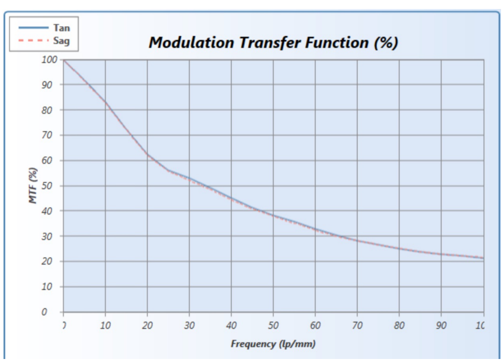


Index of Refraction of N-BK7

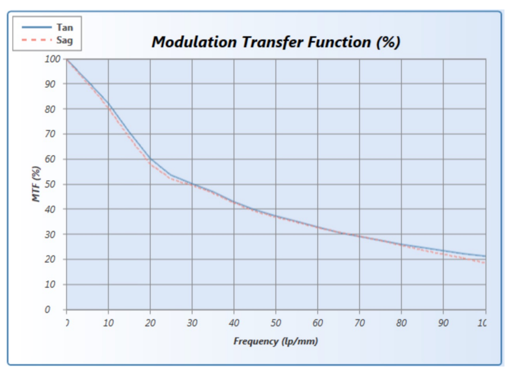
Figure 5: Transmission and Index of Refraction vs. Wavelength for N-BK7 Optic

5 Optikos LensCheck Measurements

The Optikos LenCheck can measure the effective focal length (EFL) of a lens and calculate the modulation transfer function (MTF) of a lens. For this experiment, the EFL and MTF will be measured for the achromatic doublet and the positive singlet. The LensCheck was not functioning properly when the measurements were made, so it was difficult to get consistent answers. This should be fixed now that the machine has been adjusted. I would warn users about the initial values calculated by the LensCheck. Sometimes if an optic is not focuses properly, values can be off. Use a sanity check before trusting all of the measurements.



MTF of Positive Lens



MTF of Achromat

Figure 6: MTF Data for both positive lenses.

5.1 CodeV Doublet Simulation for Comparison

Property	Specification
EPD (mm)	25
S1 RDY (mm)	61.47
S2 RDY (mm)	−44.64
S3 RDY (mm)	−129.94
S1 THI (mm)	6
S2 THI (mm)	2.5
S1 GLA	N-BK7
S2 GLA	N-SF5

(a) EO #49360 Specification

Property	Specification
EFL (mm)	100.0308
MTF @ $(10lp/mm)$	95.8%
MTF @ $(30lp/mm)$	82.6%

(b) Results from CodeV.

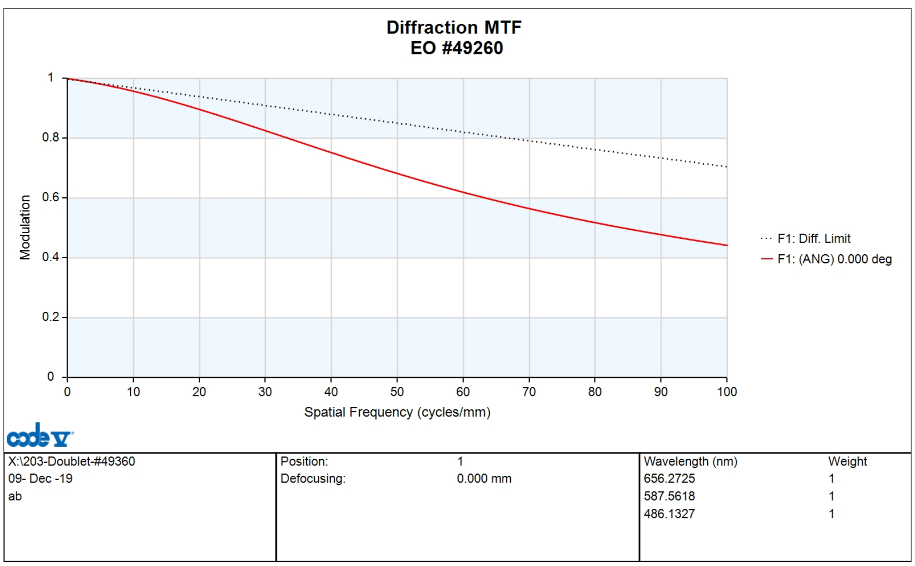


Figure 8: EO #49360 MTF from CodeV. 95.8% at 10lp/mm and 82.6% at 30lp/mm.

The theoretical values for EFL and both MTF location from CodeV are very different from those calculated on the LensCheck. This is most likely because the LensCheck was not functioning properly the day of my lab. This is an issue with the device and not necessarily that of performing the lab. The LensCheck was fixed after I had already completed that section of the lab course.

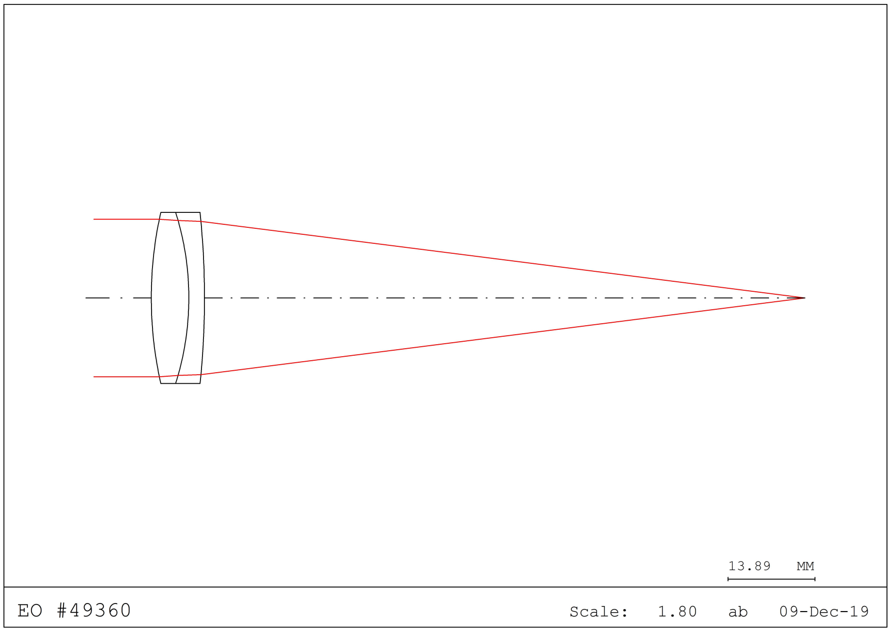


Figure 9: Achromatic Doublet Lens

```
;fir;GO

INFINITE CONJUGATES
   EFL        100.0308
   BFL         95.9519
   FFL        -98.5795
   FNO          4.0012
   IMG DIS     95.9519
   OAL          8.5000
   PARAXIAL IMAGE
    HT          0.0000
   ANG          0.0000
   ENTRANCE PUPIL
    DIA        25.0000
    THI         0.0000
   EXIT PUPIL
    DIA        25.3680
    THI        -5.5515
```

```
GEO NO
MFR  100
IFR  10
CHT FRE  Y ; TIT  'EO #49260'
GO

     DIFFRACTION LIMIT    FOCUS POSITION
      Formula  Actual      0.00000
 L/MM f/4.001 RAD  TAN    RAD  TAN
 ---- ----------------   ---------
    0 .999   .999        .999
   10 .971   .970        .958
   20 .941   .941        .897
   30 .912   .911        .826
   40 .883   .882        .753
   50 .853   .852        .683
   60 .824   .823        .620
   70 .795   .793        .566
   80 .766   .764        .519
   90 .738   .736        .478
  100 .709   .707        .443
```

6 Optical Property Comparison Table

6.1 Achromatic Doublet

Measurement Type	Metric	Measurement	Uncertainty	Spec	Uncertainty	Pass/Fail
MTF						
	MTF @(10lp/mm)	81.3%	NA	95.8%	NA	Fail
	MTF @(30lp/mm)	49.9%	NA	82.6%	NA	Fail
	EFL	97.73	4.6345	100	1	Pass

Table 1: Properties of Achromatic Doublet

6.2 N-BK7 Double Convex Singlet

Measurement Type	Metric	Measurement	Uncertainty	Spec	Uncertainty	Pass/Fail
MTF						
	MTF @(10lp/mm)	83.2%	NA	NA	NA	NA
	MTF @(30lp/mm)	52.9%	NA	NA	NA	NA
	EFL	111.06	NA	NA	NA	NA
Surface Roughness						
	Side 1 (PV)	30.63	8.418	5	NA	Fail
	Side 1(RMS)	1.717	0.1665	5	NA	Pass
	Side 2(PV)	22.3	4.198	5	NA	Fail
	Side 2 (RMS)	1.857	0.2532	5	NA	Pass
Surface Figure						
	Side 1 (PV)	0.28	NA	0.5	NA	Pass
	Side 1(RMS)	0.015	NA	0.5	NA	Pass
	Side 2(PV)	0.23	NA	0.5	NA	Pass
	Side 2(RMS)	0.009	NA	0.5	NA	Pass
Radius of Curvature						
	Side 1	101.19	0.068	103	NA	Fail
	Side 2	101.46	0.118	103	NA	Fail
Index of Refraction						
	n(500nm)	1.530196808	0	1.524	0	NA

Table 2: Properties of Positive Double Convex Lens

6.3 N-BK7 Double Concave Singlet

Measurement Type	Metric	Measurement	Uncertainty	Spec	Uncertainty	Pass/Fail
Surface Roughness						
	Side 1 (PV)	37.62	4.504	5	NA	Fail
	Side 1(RMS)	1.68	0.154	5	NA	Pass
	Side 2(PV)	231.73	161.358	5	NA	Fail
	Side 2(RMS)	2.324	0.2503	5	NA	Pass
Surface Figure						
	Side 1 (PV)	0.187	NA	0.5	NA	Pass
	Side 1(RMS)	0.017	NA	0.5	NA	Pass
	Side 2(PV)	0.227	NA	0.5	NA	Pass
	Side 2(RMS)	0.031	NA	0.5	NA	Pass
Radius of Curvature						
	Side 1	107.53	0.229	104.2	NA	Fail
	Side 2	107.38	0.153	104.2	NA	Fail
Index of Refraction						
	n(500nm)	1.530196808	0	1.524	0	NA

Table 3: Properties of Negative Double Concave Lens

7 Overall Evaluation/Discussion

The optics met up with some of their specifications. Both the positive singlet and negative singlet passed the condition for RMS surface roughness, and failed the condition for PV surface roughness. The positive and negative singlet both passed each condition for surface figure. They both failed the condition for radius of curvature. The achromatic doublet failed both of its MTF conditions, but it passed the EFL measurement.

It can be seen that measurements were accurate based on the device being used and type of measurement being made. For example, the LensCheck was broken, so it is reasonable to believe that the measurements made are not correct. Moreover, the spherometer to determine the radius of curvature of the lens was fairly primitive, so a more precise measurement may be made in the future.

The main measurements I would want to take again were the MTF and EFL measurements because of the faulty equipment. I also feel that I did not understand why the results were wrong and what needed to be done to fix them.

I was surprised at how precise the index of refraction was. The whole process of taking a measurement and then forming a regression to come up with a final index of refraction was very interesting. Besides that, I was not taken away by any of the other measurements.

The main criticism of this class is that I don't feel like I am fit to problem solve on any of the devices. If there was a mistake somewhere or something wasn't working, I don't feel like I know how to diagnose the problem. I do not think this is easily solvable in the lab, but I don't feel like we had enough time to mess around and find a solution before a TA came in to help.

Besides that, this lab course went well. I at least have a basic understanding of a wide variety of different measurement and metrology tools.