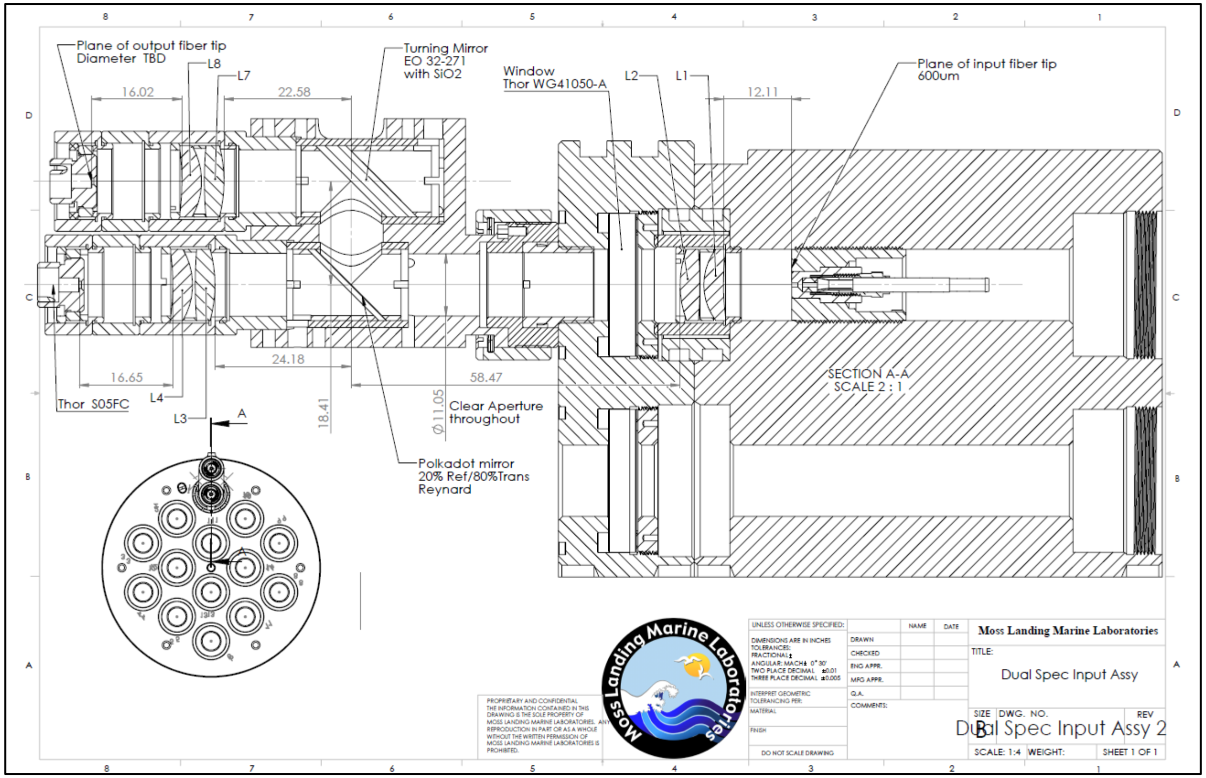
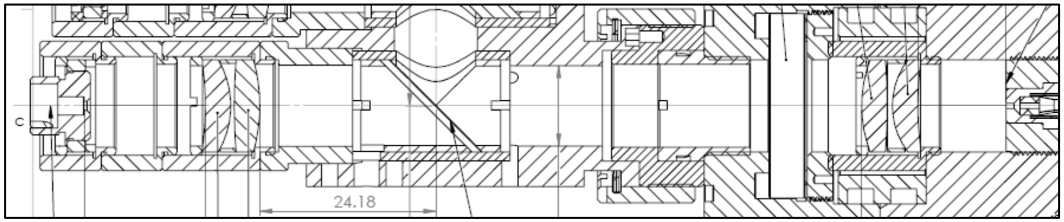
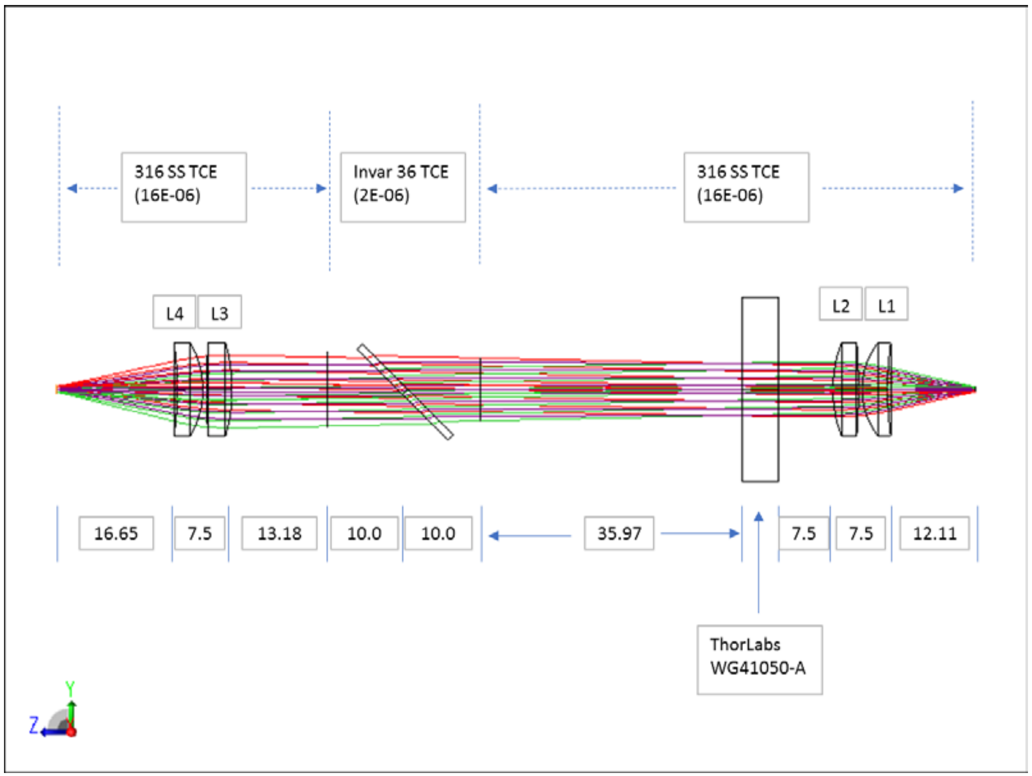
Temperature and Alignment Sensitivity, Dual Spec Input Ass'y

CJZ 09/27/17



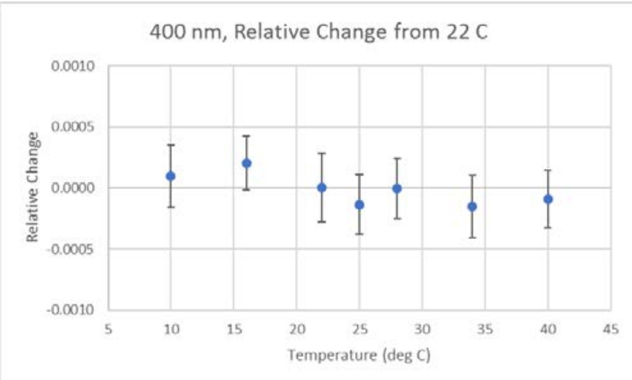
Transmitting Path

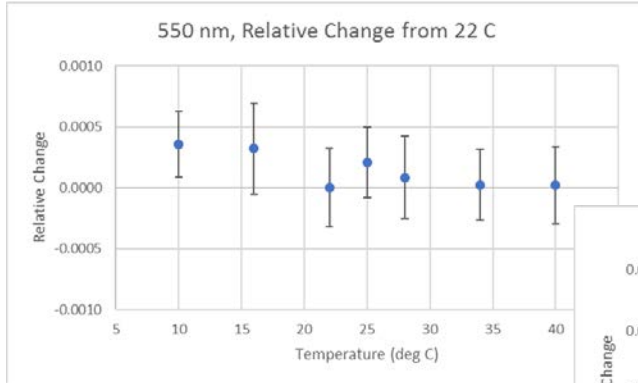


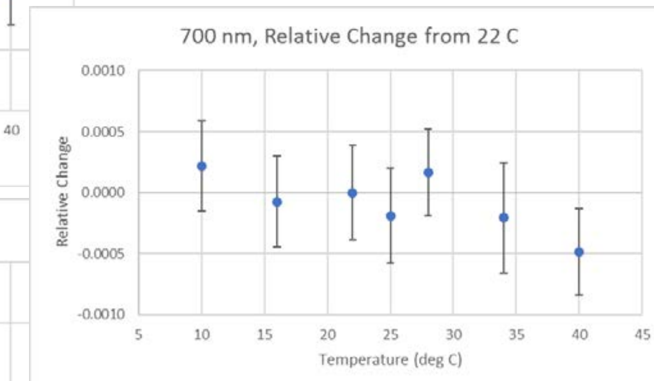


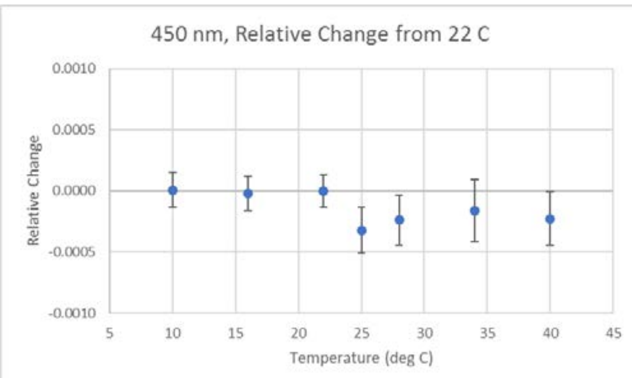
- Light propagating from right to left
- Input and Output fibers considered to be unaffected by temperature (for now…)
    - Input assumed to be 600 µm core
    - Output assumed to be 800 µm core
    - NA of both is 0.22
- Assumed 1 mm thick Polka Dot Beam Splitter (PDBS) contained in Invar 36 (TCE = 2 ppm)
- Assumed rest contained in 316 SS (TCE = 16 ppm)
- ZEMAX assigns TCE of glass and uses n(λ, T)
- Distances in mm, values referenced to 22 °C
- Traced rays over 400 nm ≤ λ ≤ 700 nm
- Traced rays from 10° C ≤ T ≤ 40° C
- In plots to follow, points are referenced to throughput at 22 °C for each wavelength, so they are relative throughput
    - Each point is mean over 10 raytraces
    - Error bars is spread, k = 2 (Standard Deviation of the Mean) SDOM

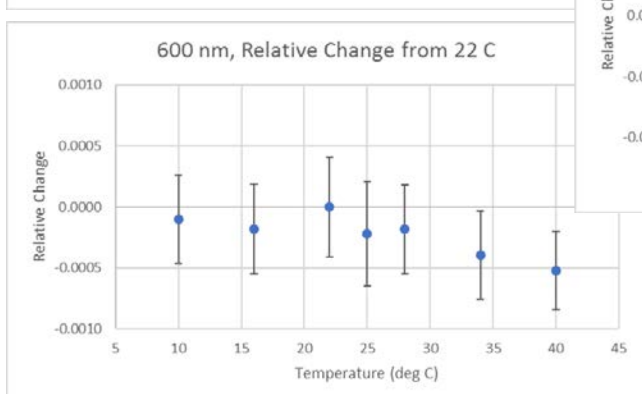
Calculated Temp. Sensitivity of Throughput, Transmitting Path

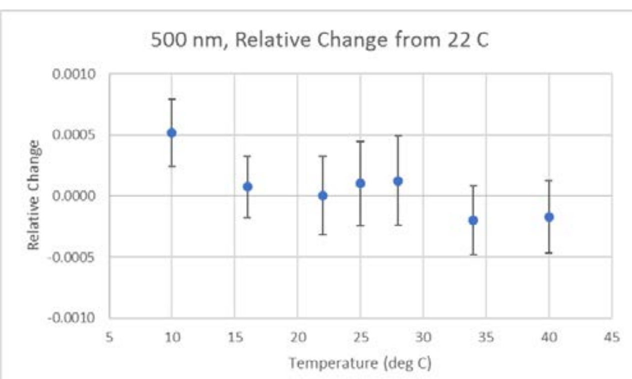


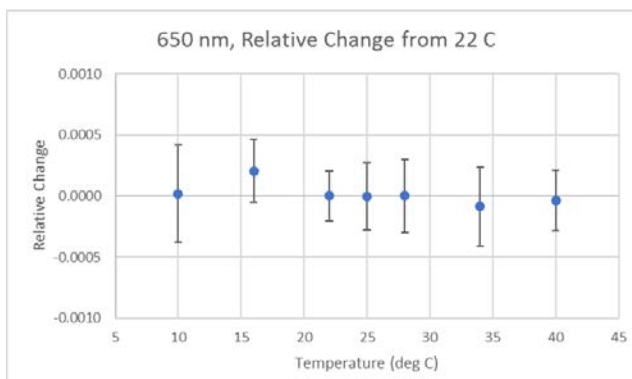






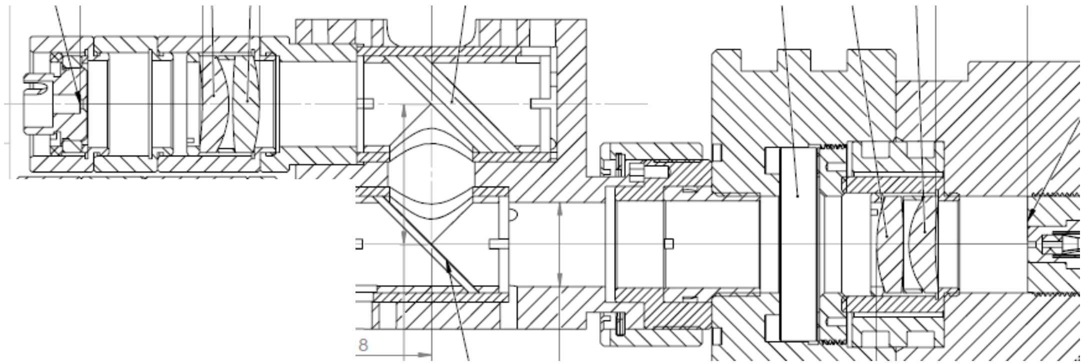


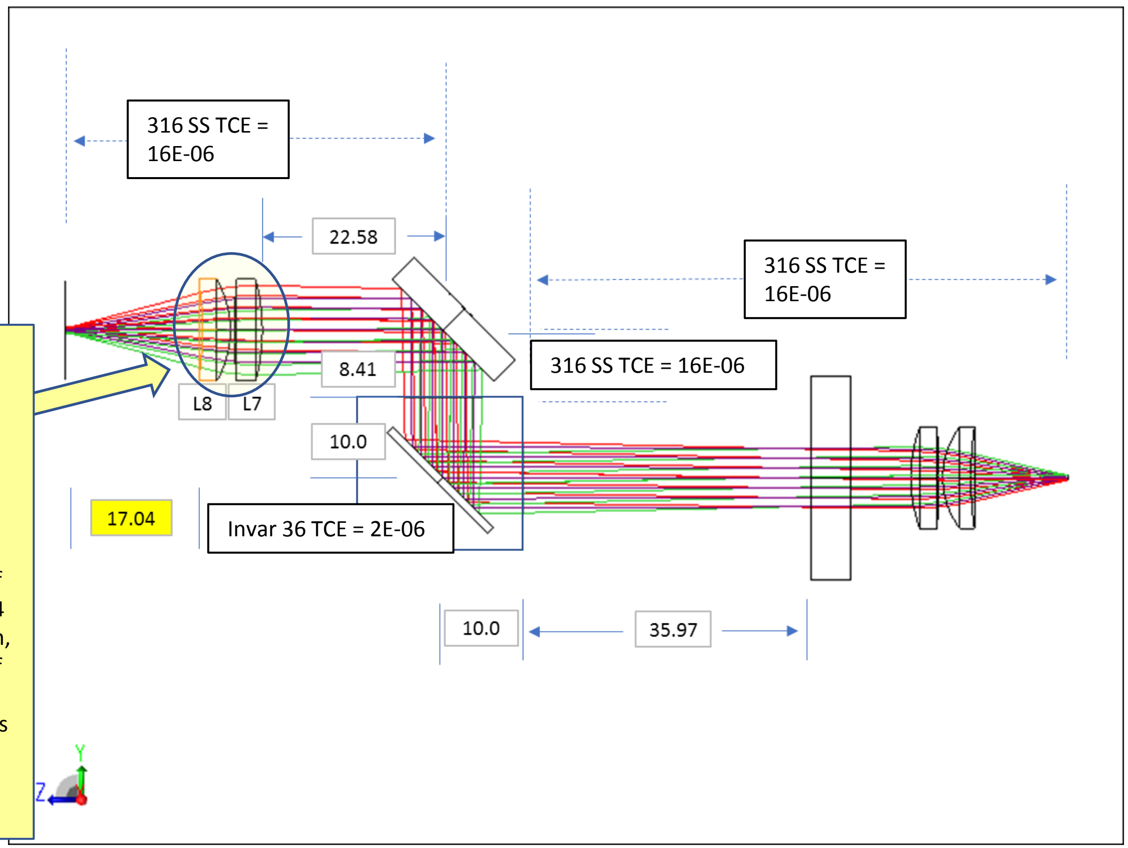




+/- 0.1 % easily contains all data including error bars

Reflecting Path

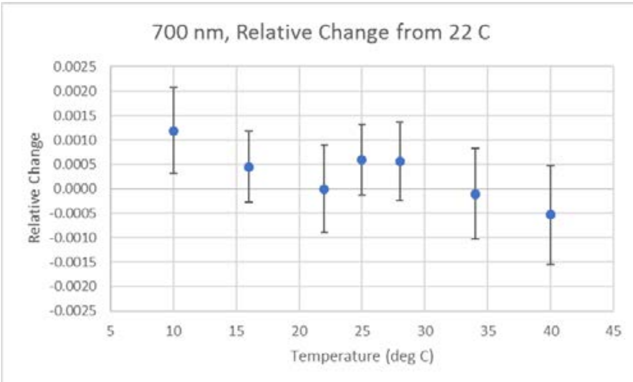


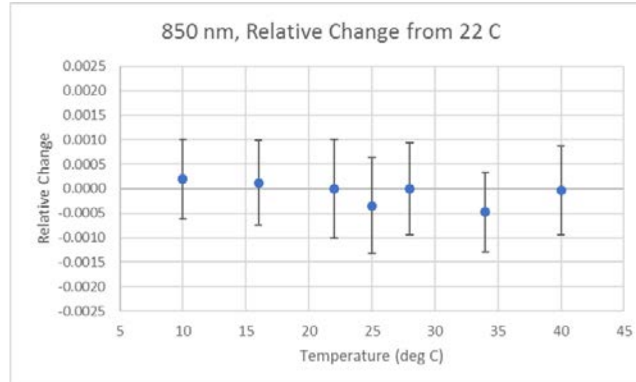


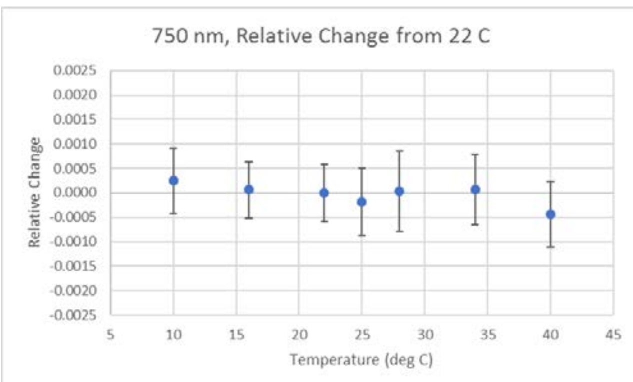
Worry that clear aperture of L7 is not large enough to pass all rays (non-sequential trace to be performed with parts in mounts). In transmitting path, distance from front of PDBS to L3 is about 24 mm; in reflecting path, distance from front of PSBS to L7 is about 41 mm. Although beam is collimated it still diverges so beam is bigger!

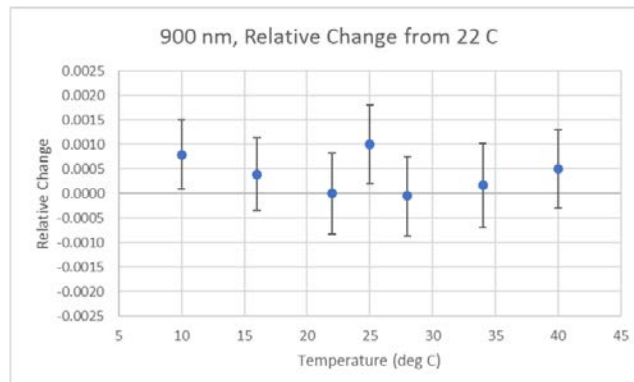
- Light propagating from right to left
- NOTE back focus distance from L8 changed from 16.02 mm to 17.04 mm (so that L7 and L8 can be used with L1 and L2)
- 700 nm ≤ λ ≤ 950 nm
- 10 °C ≤ T ≤ 40 °C
- Again referencing throughput to that at 22 °C…

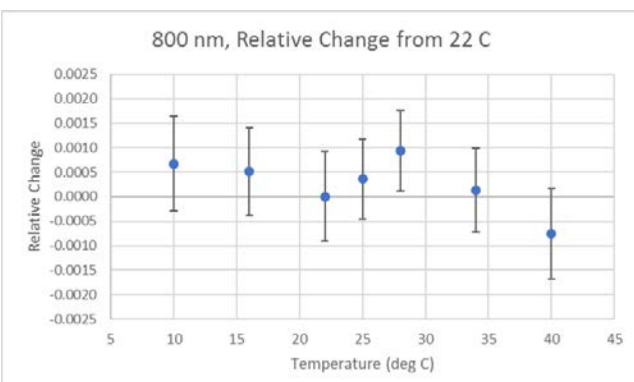
Calculated Temp. Sensitivity of Throughput, Reflecting Path

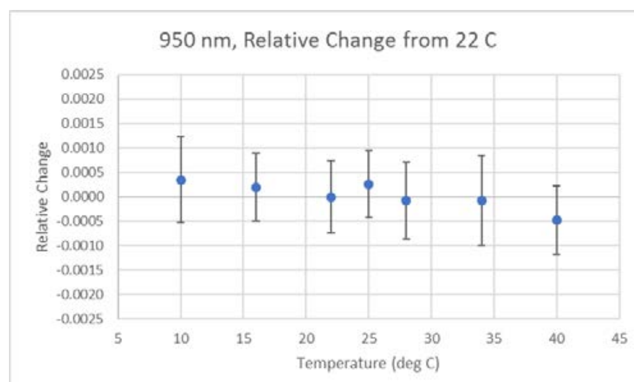












+/- 0.2 % contains all data including error bars

Most Critical Alignment Parameters, Ordered by Their Impact on Throughput

Transmitting Path

Worst offenders:

Type	surf #	surf #	Value	Change	norm to max	Description
TEDY	1	2	-0.2	0.0004227	1.00	-Y Decentering of L1
TEDY	1	2	0.2	0.0004227	1.00	+Y Decentering of L1
TTHI	1	2	-0.2	0.00034393	0.81	-Gap in L1, L2
TEDY	3	4	-0.2	0.00021015	0.50	Decentering of L2
TEDX	1	2	-0.2	0.00013166	0.31	-X Decentering of L1
TEDX	1	2	0.2	0.00013166	0.31	+X Decentering of L1
TTHI	7	8	0.2	7.79E-05	0.18	+Gap between window and PDBS
TEDY	16	17	0.2	3.91E-05	0.09	+Y Decentering of L4
TEDY	14	15	0.2	3.89E-05	0.09	+Y Decentering of L3
TEDX	3	4	0.2	2.41E-05	0.06	+X Decentering of L2
TEDX	3	4	-0.2	2.41E-05	0.06	-X Decentering of L2
TETX	1	2	-0.2	2.83E-06	0.01	-X tilt of L1

Reflecting Path

Worst offenders:

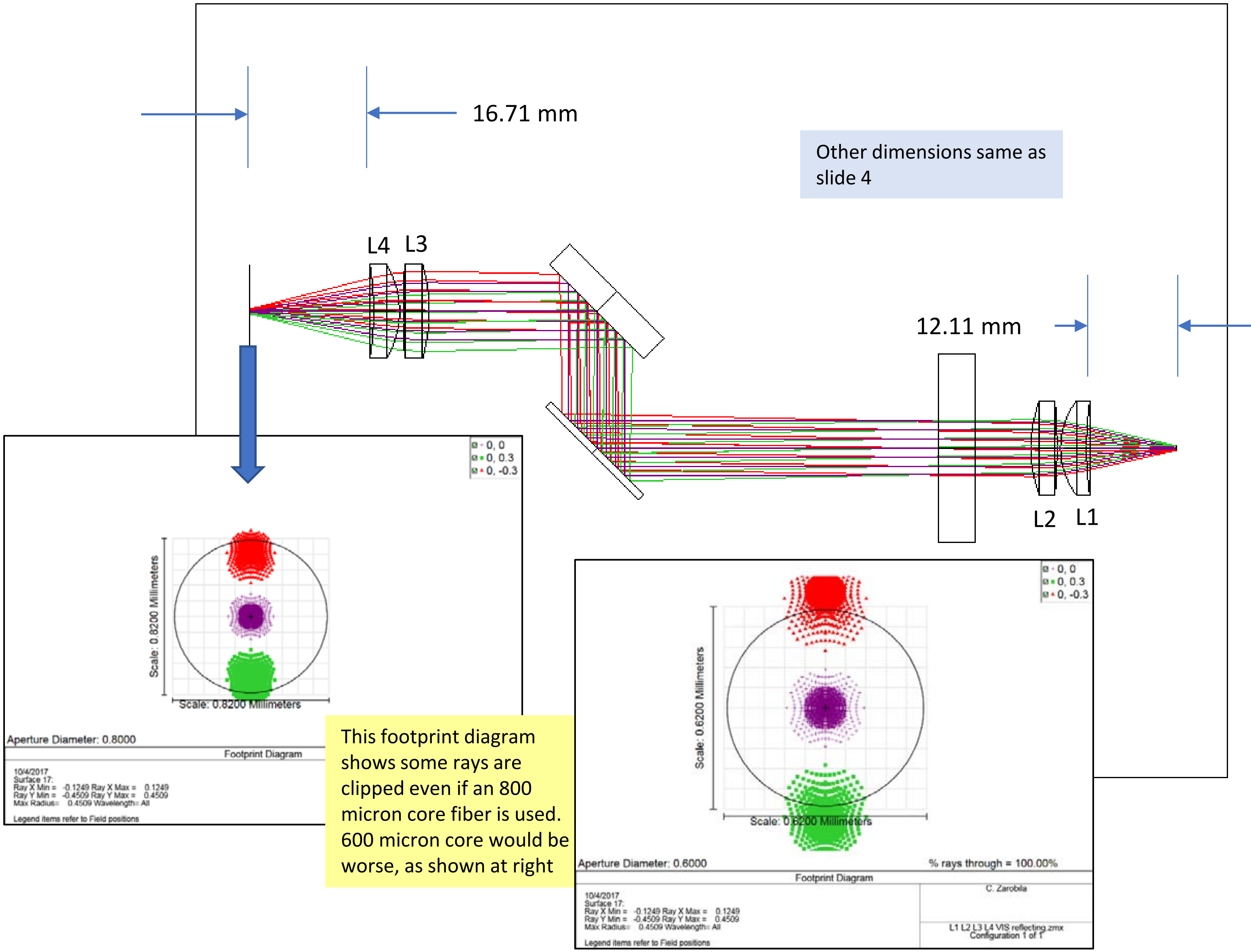
Type	surf #	surf #	Value	Change	norm to max	Description
TEDY	1	2	-0.2	0.001285	1.00	-Y Decentering of L1
TEDY	1	2	0.2	0.001285	1.00	+Y Decentering of L1
TEDX	1	2	-0.2	0.001285	1.00	-X Decentering of L1
TEDX	1	2	0.2	0.001285	1.00	+X Decentering of L1
TTHI	1	2	-0.2	0.000929	0.72	-Gap in L1, L2
TEDX	3	4	0.2	0.000864	0.67	+X Decentering of L2
TEDX	3	4	-0.2	0.000864	0.67	-X Decentering of L2
TEDY	3	4	-0.2	0.000864	0.67	-Y Decentering of L2
TEDY	3	4	0.2	0.000864	0.67	+Y Decentering of L2
TTHI	10	11	-0.2	0.00027	0.21	-Gap between PDBS and turning mirror
TTHI	7	8	0.2	0.00027	0.21	+Gap between window and PDBS
TTHI	2	4	-0.2	0.00026	0.20	-Gap between L2 and window
TETX	8	8	0.2	0.000215	0.17	+X tilt of PDBS
TETX	8	8	-0.2	0.000215	0.17	-X tilt of PDBS
TTHI	7	8	-0.2	0.000214	0.17	-Gap between window and PDBS
TTHI	10	11	0.2	0.000214	0.17	+Gap between PDBS and turning mirror
TETY	8	8	0.2	0.000107	0.08	+Y tilt of PDBS
TETY	8	8	-0.2	0.000107	0.08	-Y tilt of PDBS
TTHI	11	12	-0.2	6.44E-05	0.05	-Gap between turning mirror and L7

- These mechanical tolerance parameters are ordered from the having the greatest sensitivity on throughput (top), to least sensitivity (bottom); "norm to max" shows their relative impact w.r.t. the worst offender
  - "Value" is the alignment error
- TEDY is decentering along Y
- TEDX is decentering along X
- TTHI is gap thickness
- TETX is tilt about X in degrees
- TETY is tilt about Y in degrees
- For example…
  - in the transmitting path, decentering of L2 from the optical axis along -Y has ½ the effect on throughput compared to decentering L1 in +/-Y
  - in the reflecting path, an error in the tilt about X of the PDBS has only about 17% of the effect that decentering of L1 has on throughput
- In general, take great care to center L1 and L2 on the optical axis as loose tolerances on these will have the greatest effect on throughput. The impact of the rest on alignment sensitivity follow in order from top to bottom according to "norm to max"
- Tolerances on lens and window curvatures, thickness, wedge, irregularity, refractive index, etc. have been ignored

Update 10/2017

- Swapped VIS and NIR channels
  - VIS is reflecting, NIR is transmitting
- Titanium cell (TCE = 9E-06) to hold PDBS instead of Invar 36 (2E-06)
- Changed thickness of PDBS to 1.5 mm (remains fused silica)

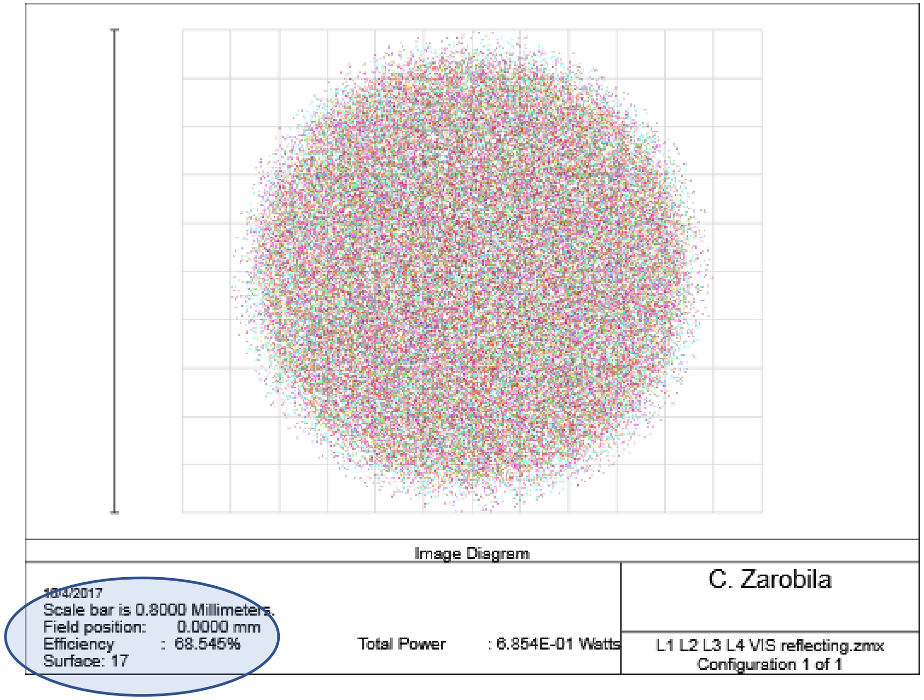
VIS Reflecting: L1, L2, L3, L4

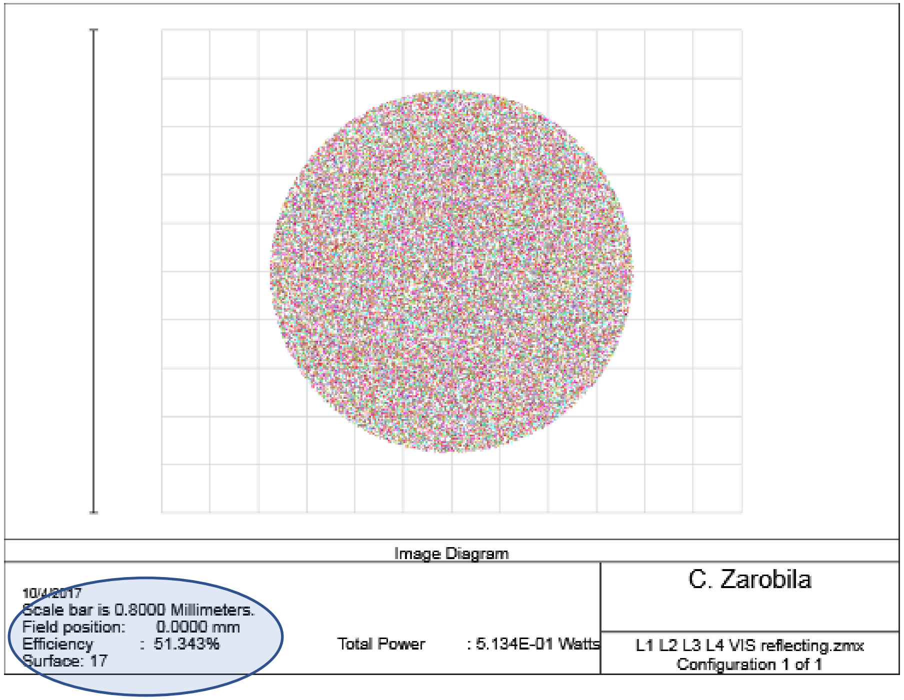


Other dimensions same as slide 4

This footprint diagram shows some rays are clipped even if an 800 micron core fiber is used. 600 micron core would be worse, as shown at right

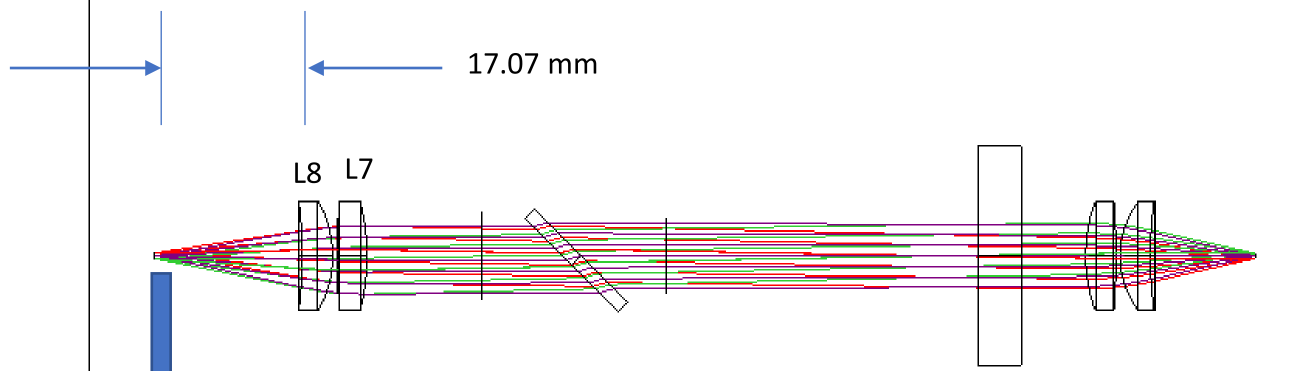
Illustrating Light Loss for 0.22 NA fiber, 800 micron vs 600 micron. 400 nm ≤ λ ≤ 700 nm, simple AR coatings

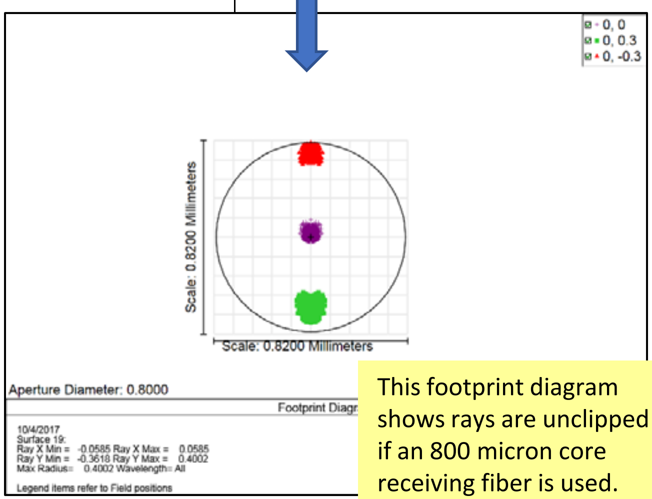




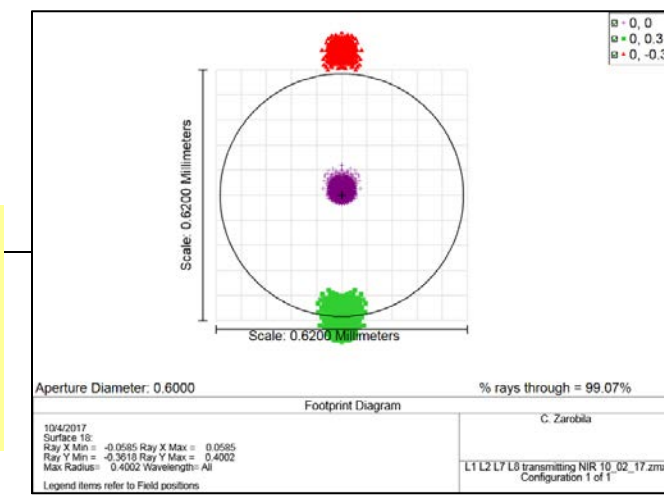
Expect about 25% less light to get through if using a 600 micron core fiber at the image plane vs. 800 micron core

NIR transmitting: L1, L2, L7, L8

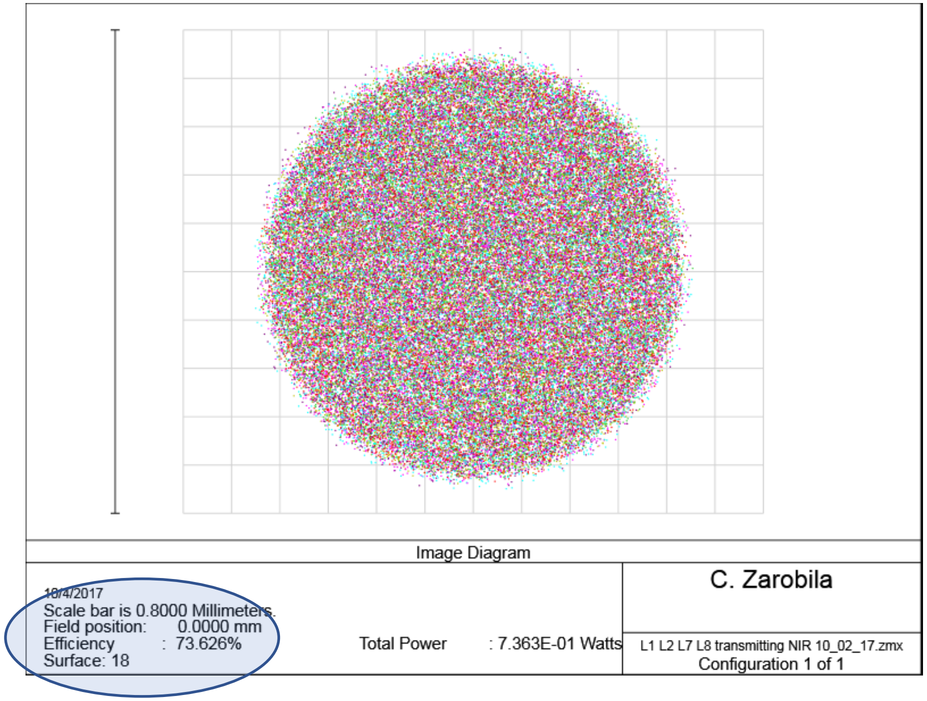


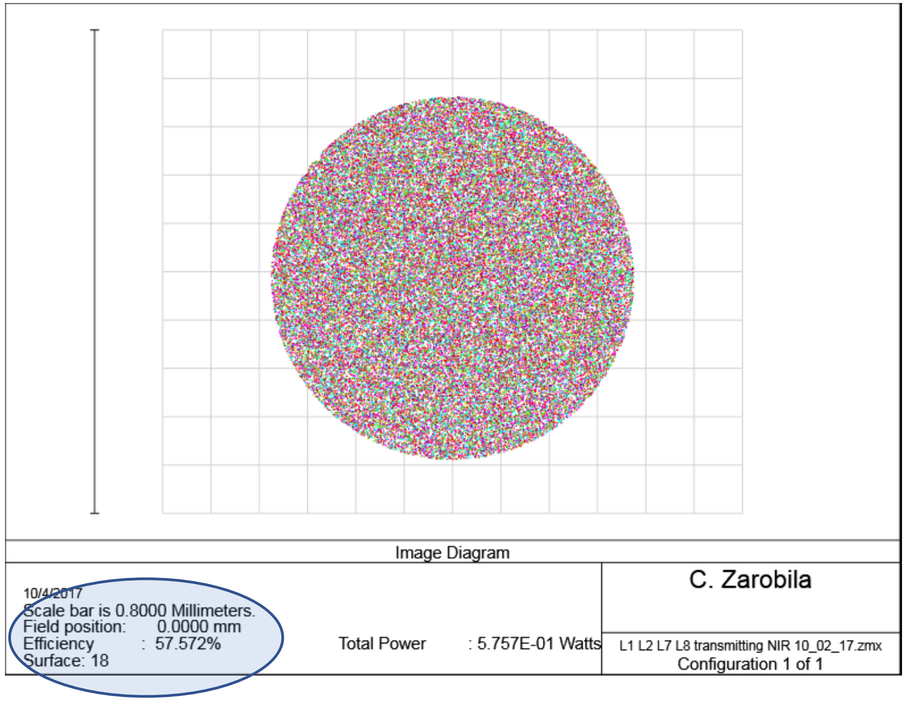


This footprint diagram shows rays are unclipped if an 800 micron core receiving fiber is used. Rays are clipped with a 600 micron core, as shown at right



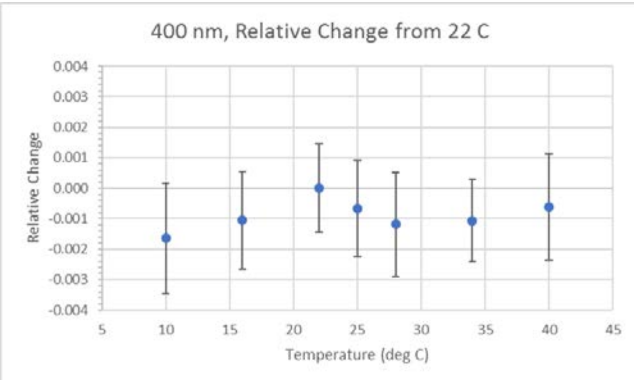
Illustrating Light Loss for 0.22 NA fiber, 800 micron vs 600 micron. 700 nm ≤ λ ≤ 950 nm, simple AR coatings

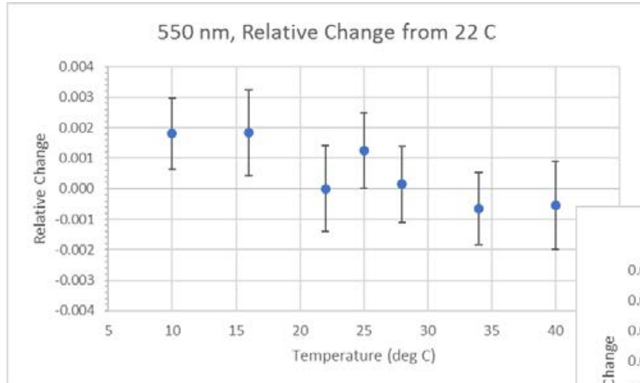


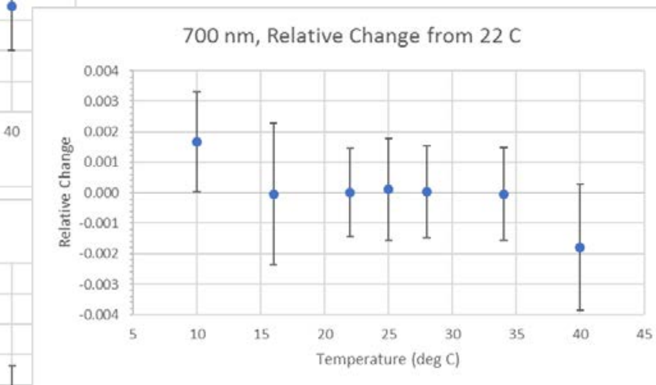


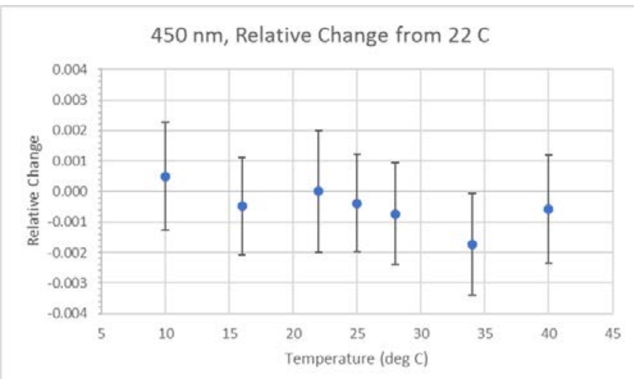
Expect about 22% less light to get through if using a 600 micron core fiber at the image plane vs. 800 micron core

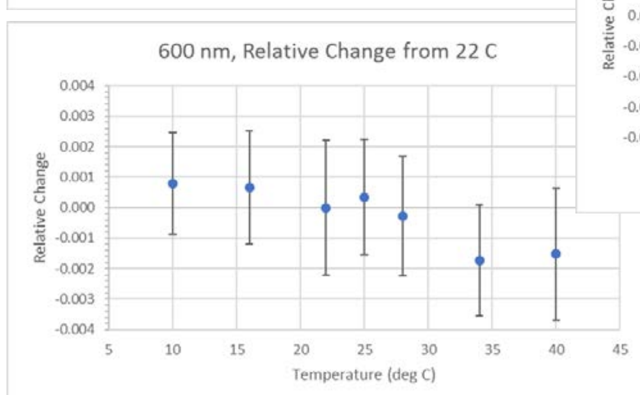
Calculated Temp. Sensitivity of Throughput, Reflecting Path (now visible λs)

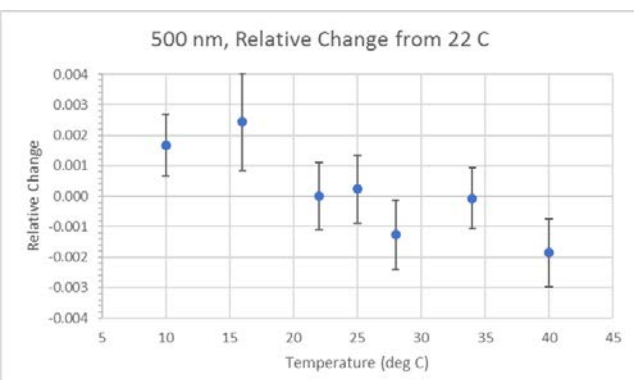


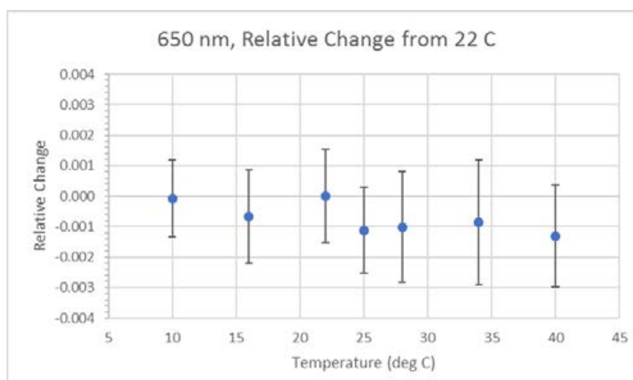






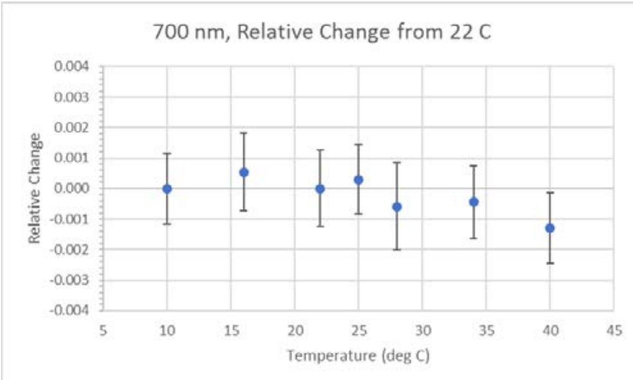


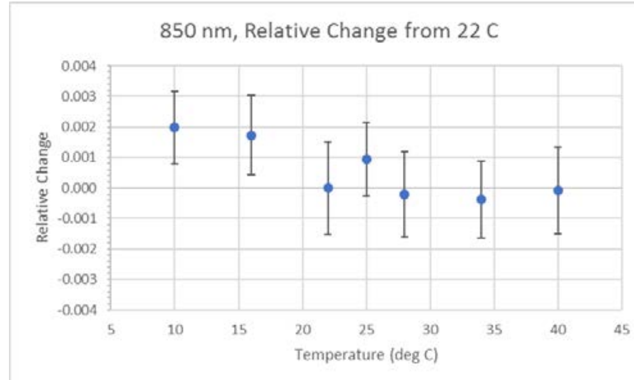


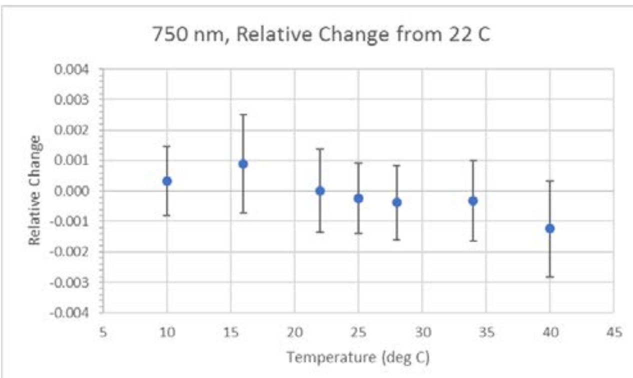


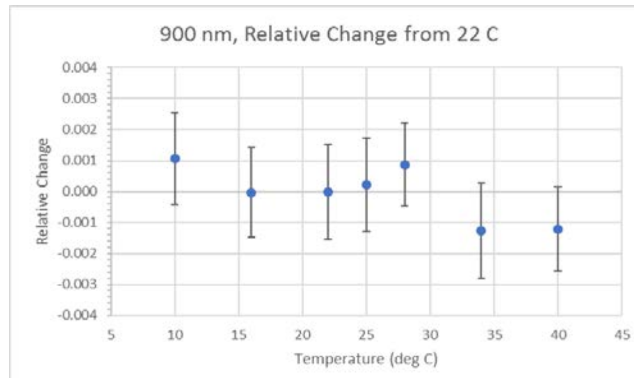
Sensitivity is worse, probably because of 600 micron receiving fiber. +/- 0.4 % contains all data including k = 2 error bars

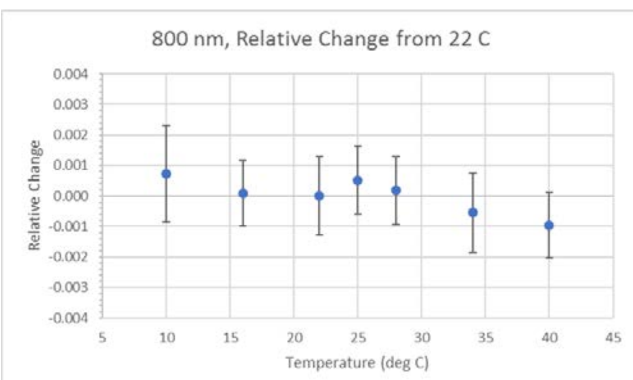
Calculated Temp. Sensitivity of Throughput, Transmitting Path (now NIR λs)

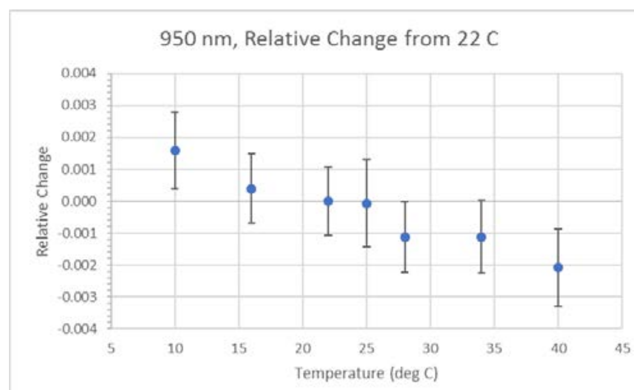










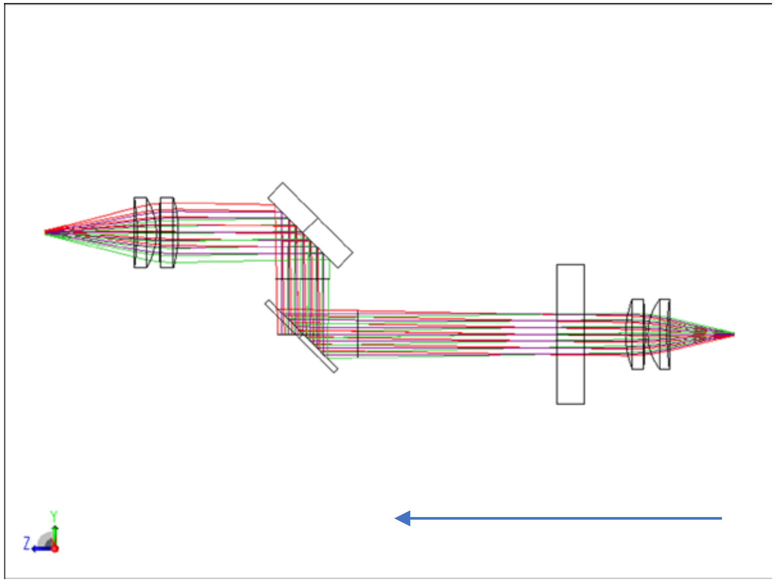


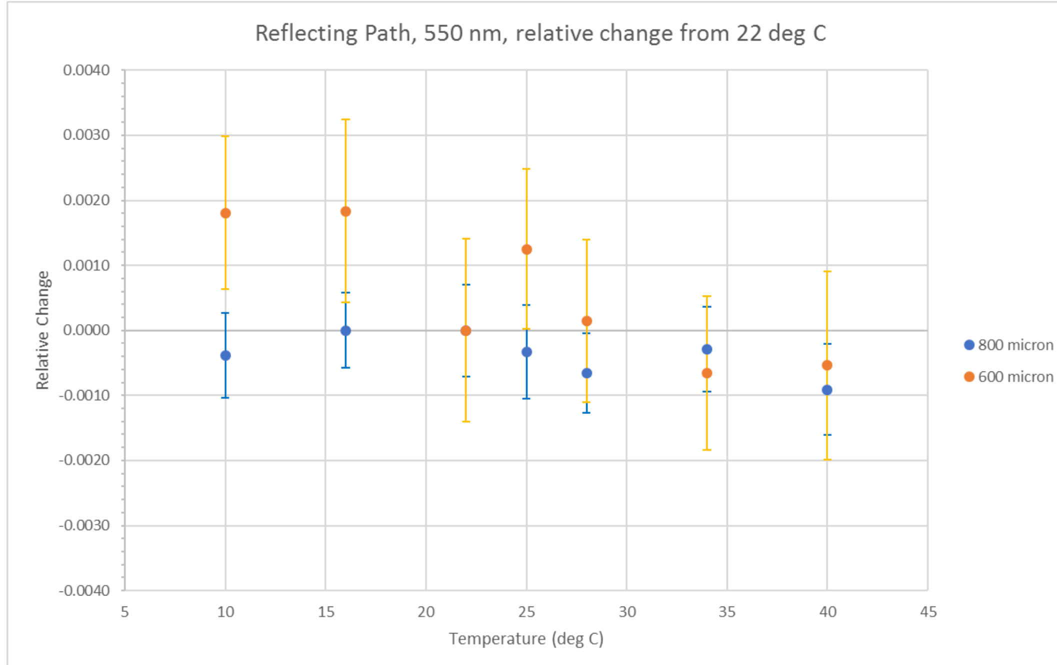
Sensitivity is worse, probably because of 600 micron receiving fiber. +/- 0.35 % contains all data including k = 2 error bars

Update 10/17/17

- Changed receiver fiber to 800 micron core
- Look only at one wavelength
  - 550 nm, reflecting path
  - 750 nm, transmitting path
- Compare to 600 micron core receiver…

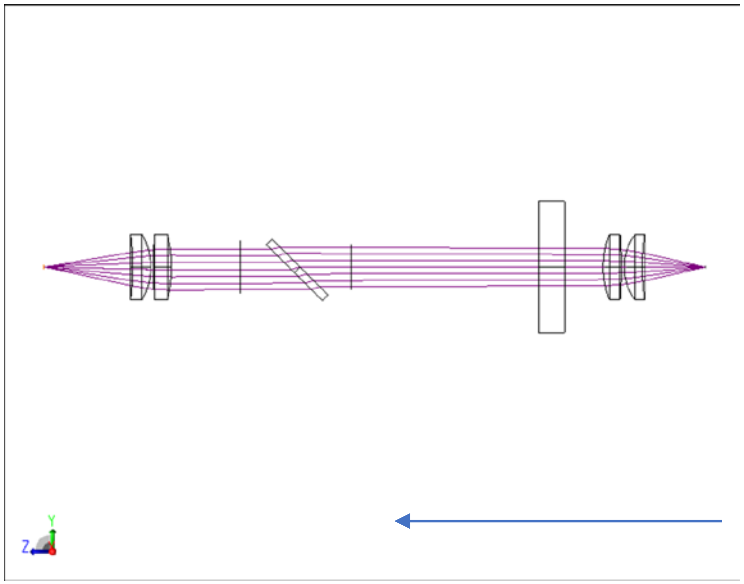
550 nm, Reflecting

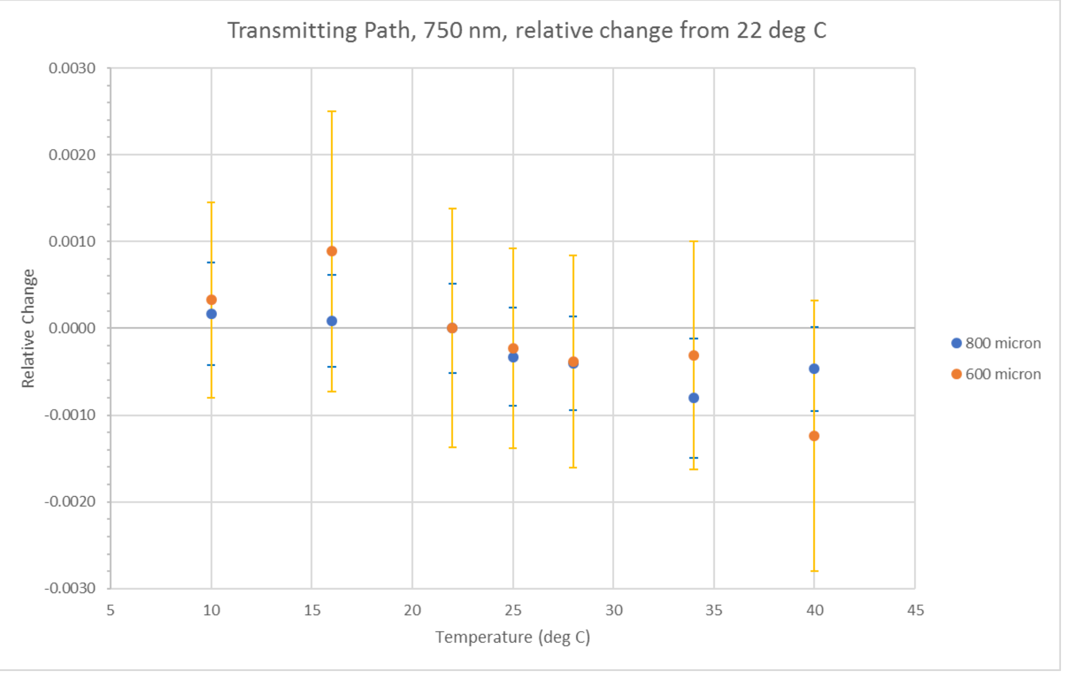




- Old data (600 micron core) in orange
- New data (800 micron core) in blue
- Again plotting relative change in throughput w.r.t. 22°C over 10 raytraces
    - Error bars k = 2
    - Same number of rays traced so it is a direct comparison
- Using "RMS" calculation to assign a single number to each for comparison purposes…
    - 600 micron, RMS relative change = 0.0011; 800 micron, RMS relative change = 0.0005
    - 600 micron, RMS uncertainty = 0.0013; 800 micron, RMS uncertainty = 0.0007

750 nm, Transmitting





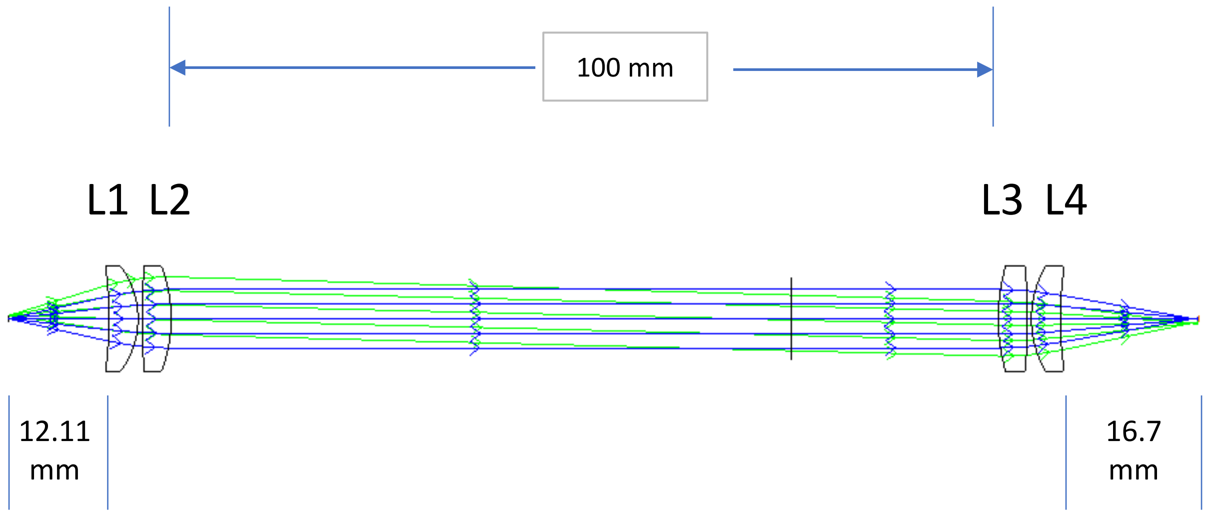
- Old data (600 micron core) in orange
- New data (800 micron core) in blue
- Again plotting relative change in throughput w.r.t. 22°C over 10 raytraces
    - Error bars k = 2
    - Same number of rays traced so it is a direct comparison
- Using "RMS" calculation to assign a single number to each for comparison purposes…
    - 600 micron, RMS relative change = 0.0006; 800 micron, RMS relative change = 0.0004
    - 600 micron, RMS uncertainty = 0.0013; 800 micron, RMS uncertainty = 0.0006

Update 11/01/17

Shutter-Collimator, Blue channel
("Blue" implies L1, L2, L3, and L4 are used)

What happens for 600 micron core input, then 800 micron core output followed by 600 micron core output?

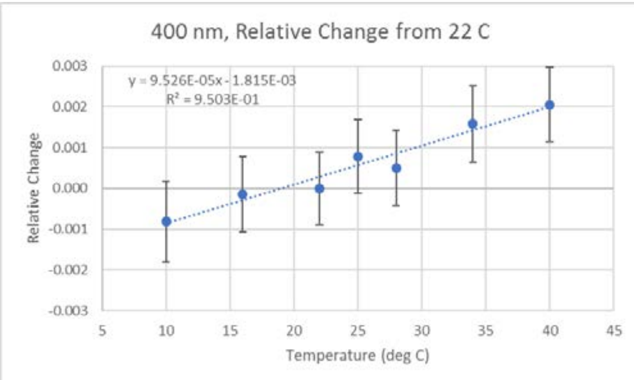
Layout

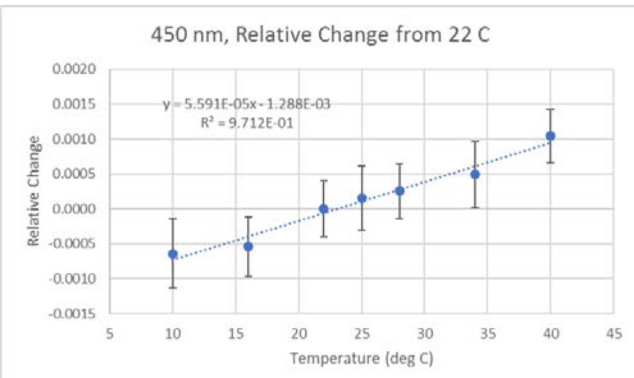


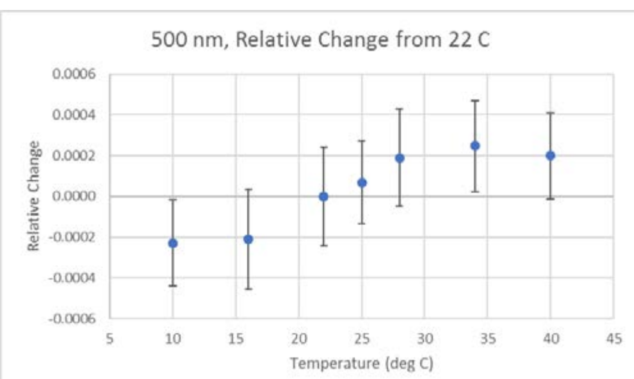
550 nm chosen as reference wavelength for merit function RMS spot size minimization at 22 deg C. Back focus distance comes from that assumption.

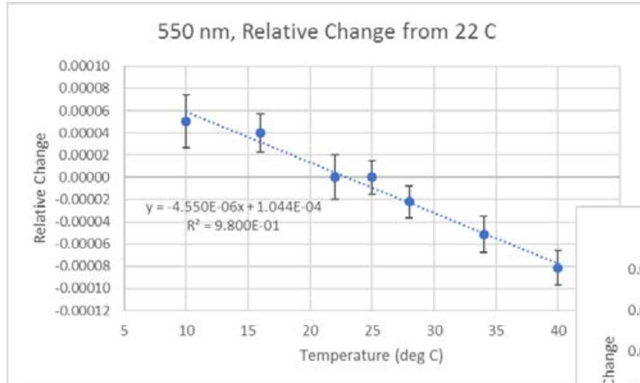
Aluminum (TCE 16 ppm) used for all mounts.

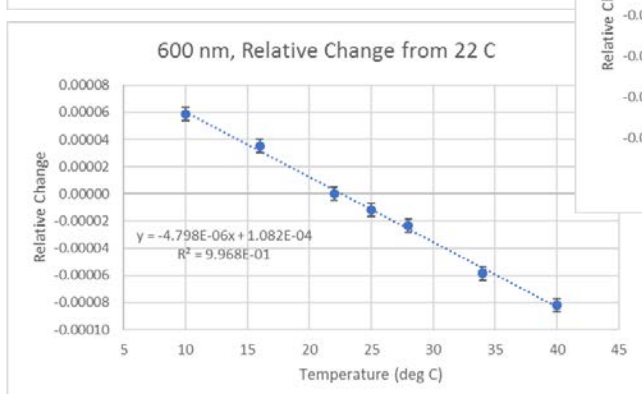
Calculated Temperature Sensitivity of Throughput: 800 micron receiver

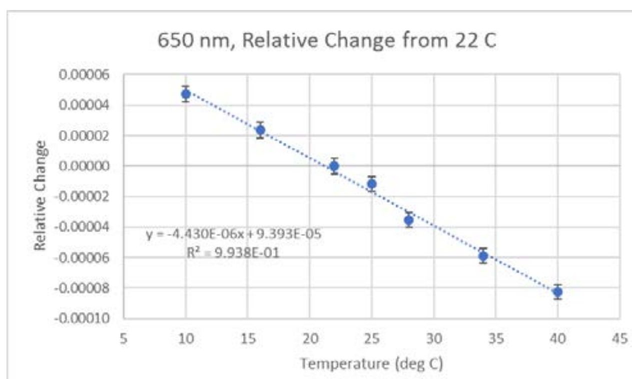


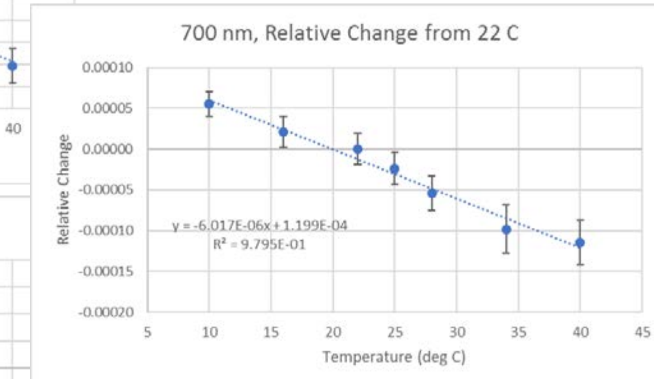








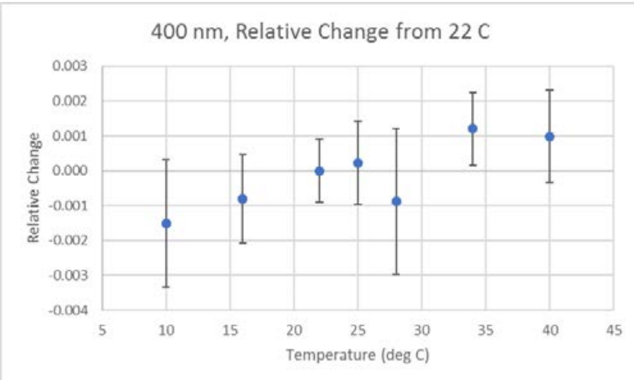


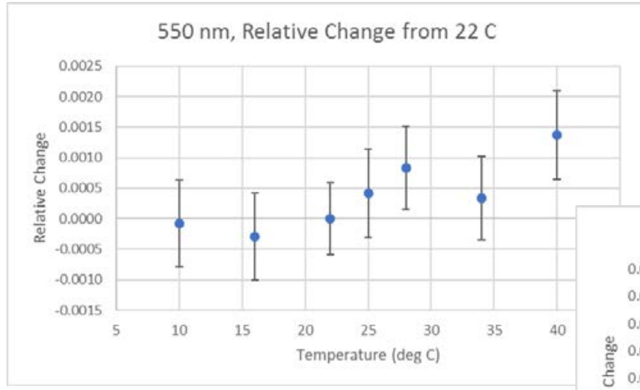


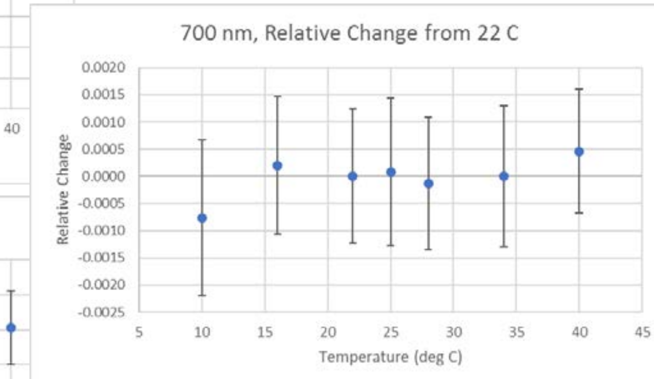
Note reduced scales and obvious trends, and trend reversal. At 550 nm, sensitivity is -4.55E-04%/°C.

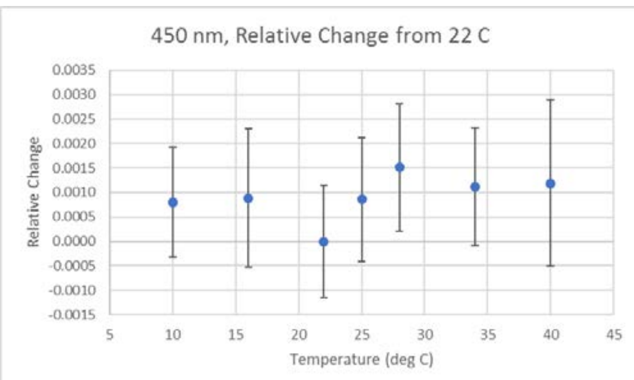
This configuration, 600 micron source and 800 micron receiver, was the original design configuration used to optimize lens curvatures.

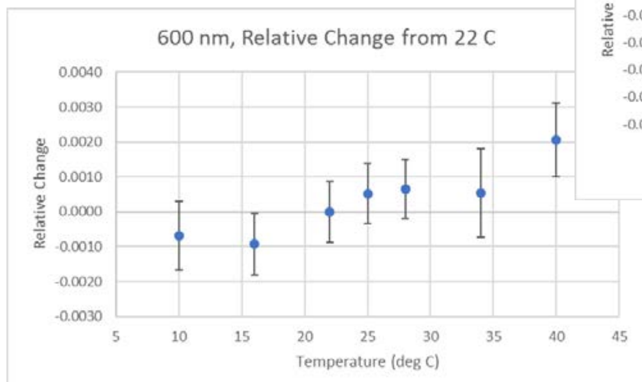
Calculated Temperature Sensitivity of Throughput: 600 micron receiver

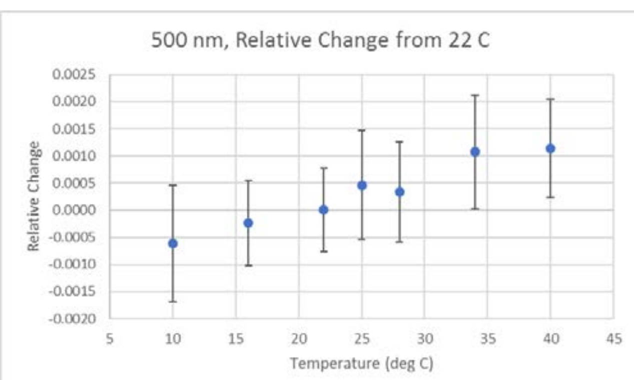


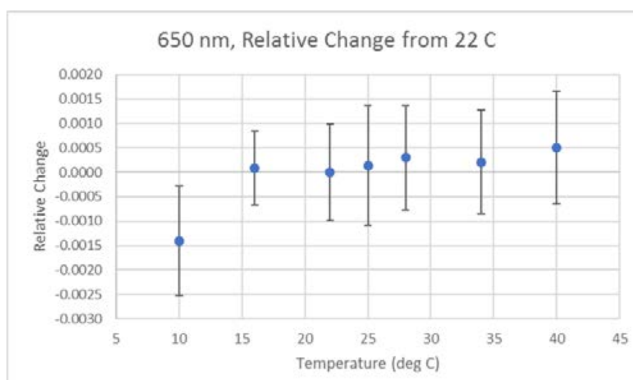












Note scale increase.

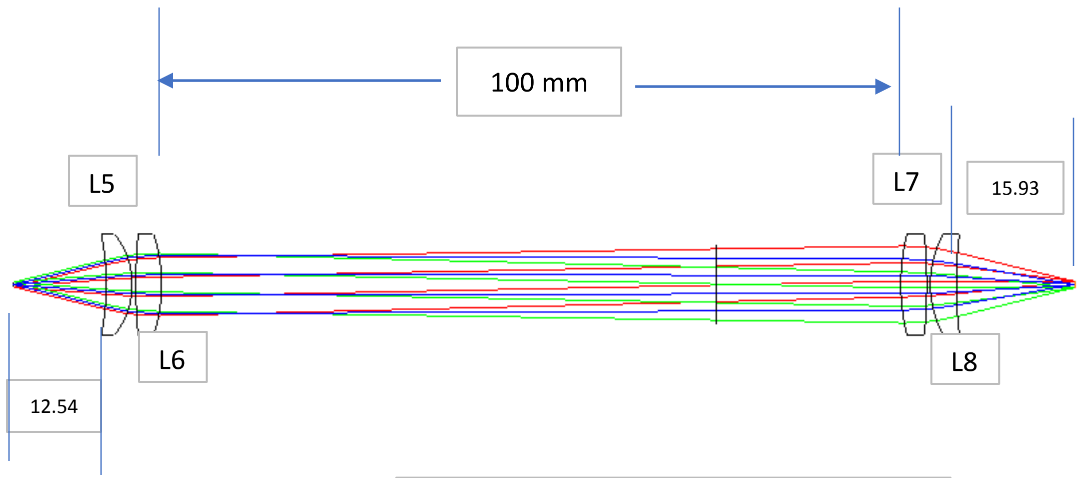
There may be a trend, but, no obvious reversal.

Update 11/03/17

Shutter-Collimator, Red channel
("Red" implies L5, L6, L7, and L8 are used)

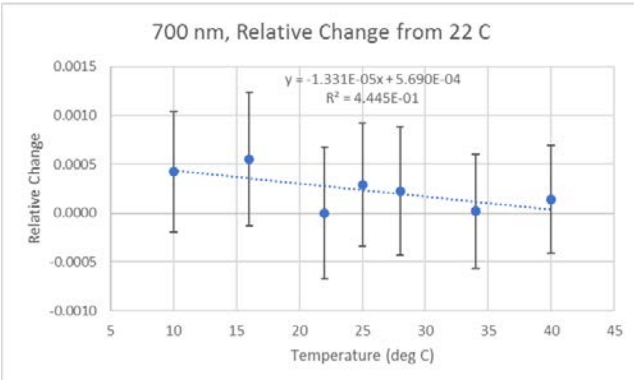
What happens for 600 micron core input, then 800 micron core output followed by 600 micron core output?

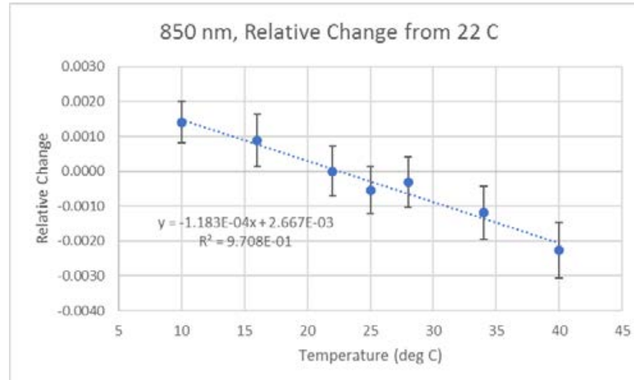
Layout

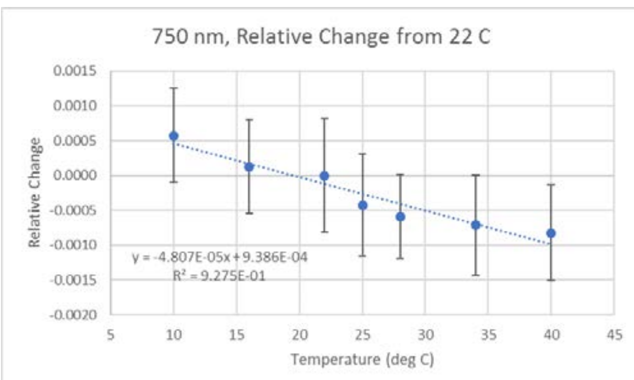


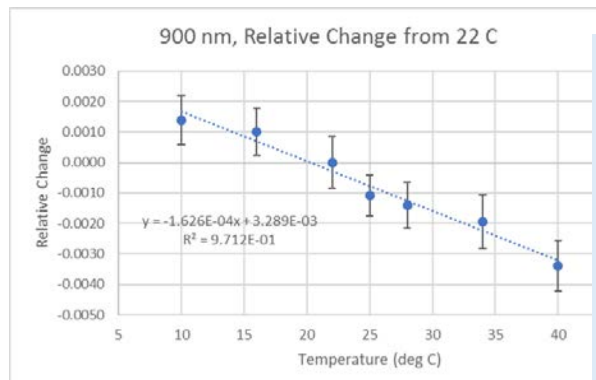
750 nm chosen as reference wavelength for merit function RMS spot size minimization at 22 deg C. Back focus distance comes from that assumption.

Calculated Temperature Sensitivity of Throughput, 800 micron Receiver



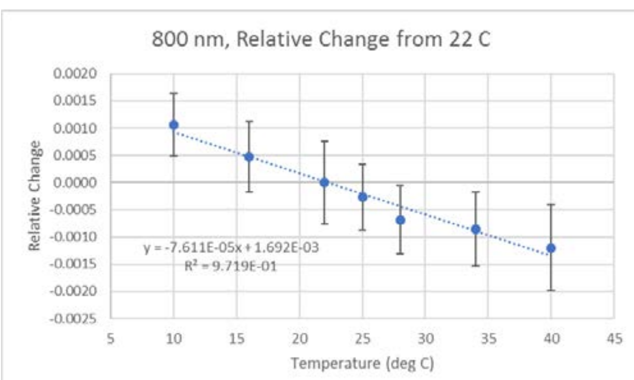


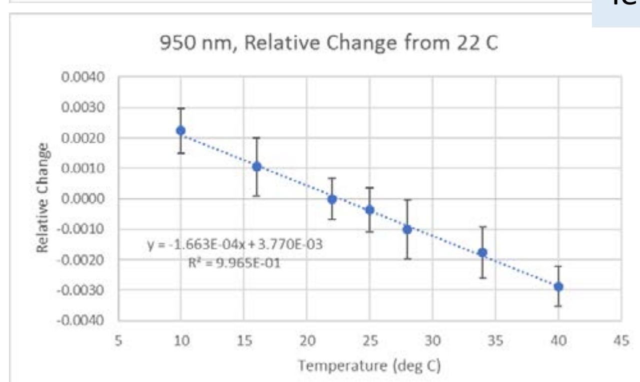




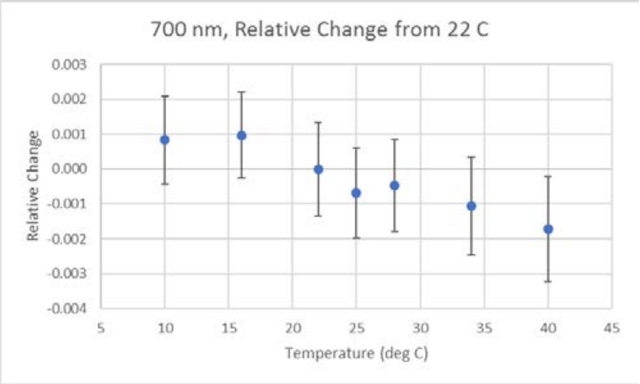
Note obvious trends. At 750 nm, sensitivity is -4.8E-03%/°C.

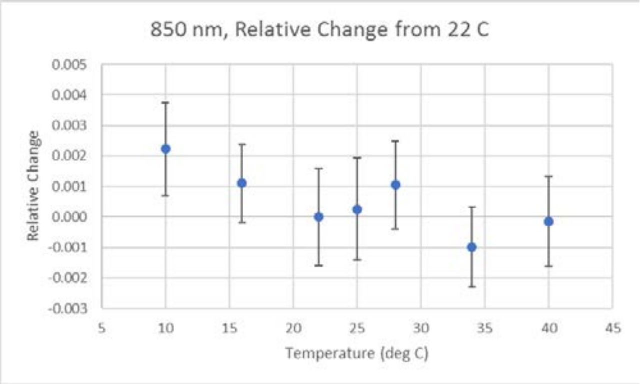
This configuration, 600 micron source and 800 micron receiver, was the original design configuration used to optimize lens curvatures.

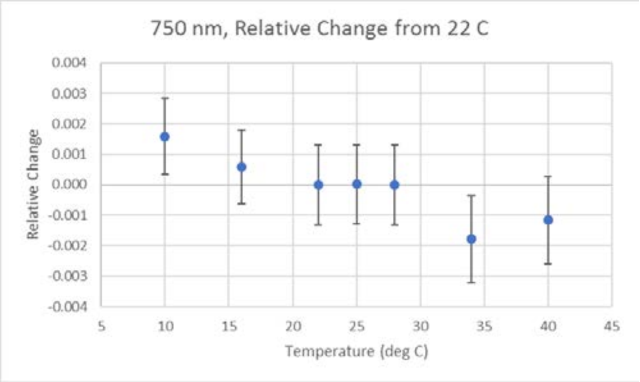


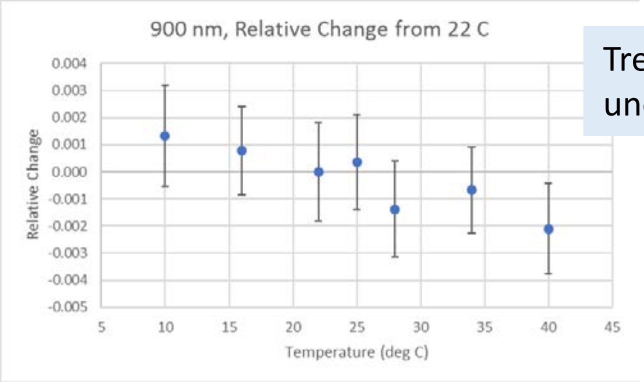


Calculated Temperature Sensitivity of Throughput, 600 micron Receiver









Trends are still there, but uncertainty is larger