

Lectures Notes on Optical Design using Zemax OpticStudio

Lecture 16 Thermal Analysis



Ahmet Bingül

Gaziantep University Department of Optical Engineering

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What is Thermal Analysis?

Optical systems are used in a variety of environments. Therefore, it is required to model effects of temperature, pressure, etc, in an optical system design.

Modelling of temperature effects on optical system is known as Thermal Analysis

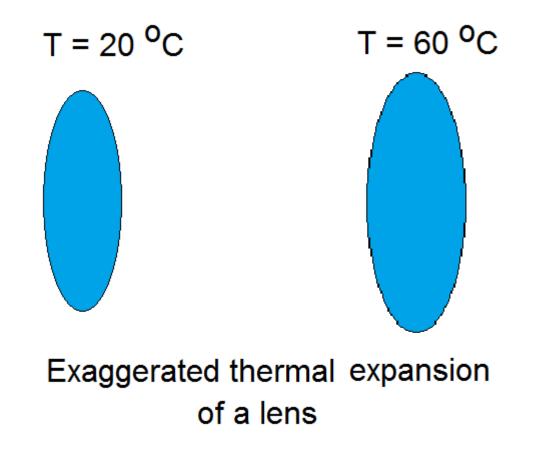
It is important to include temperature effects, if temperature change is more than 40 degrees since

- Glass expands / contracts
- Mechanical holders expands / contracts

In military applications, we may use effect of temperature changes in the range ±50 °C.

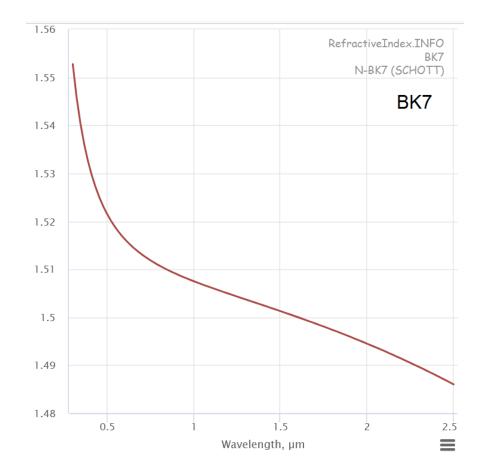
Temperature and Lens Geometry

- Glass expands isotropically (uniformly in all directions).
- That is radii and thickness expand at the same rate.



Temperature, Pressure and Index of Ref.

- For many optical materials the refractive index decreases as the wavelength increases.in optical region.
- Refractive index
 - of a glass decreases as the temperature of medium increases.
 - of air increases as the pressure of the medium increases.
- Hence, the designer should take these factors into account when making the analysis.



Temperature and Focal Length of a Lens

Considering the simple case of a single element thin lens, the change in focal length (Δf) of the lens with temperature is given by: $\gamma = \text{thermo-optical coefficient of } f$

$$\Delta f = -\gamma f \Delta T = -\left(\frac{dn/dT}{n-1} - \alpha_L\right) f \Delta T$$

$$\gamma$$
 = thermo-optical coefficient of the lens
dn/dT = refractive index change with temperature
n = refractive index of the lens
 α_L = thermal expansion coefficient (TCE) of the lens
f = focal length of the lens
 ΔT = temperature change

Thermal effects are especially very important in IR applications. Assume that we have a 75-mm-diameter f/1.5 Germanium lens with a focal length of 112.5 mm

Depth of focus: $\delta = 0.046 \text{ mm}$ Change in Focal length: $\Delta f = 0.599 \text{ mm}$ (for $\Delta T = 40 \text{ °C}$)

The difference is very large. Therefore, relatively large temperature change is a very serious problem in thermal infrared systems.

TCE of Some Materials

Glass	<u>TCE (1/°C)</u>
N-BK7	$7.1 x 10^{-6}$
N-SF2	$7.1 x 10^{-6}$
N-SF5	$7.9x10^{-6}$
N-F2	6.7x10 ⁻⁶
N-LAF35	5.3x10 ⁻⁶
POLYCARB	60.0x10 ⁻⁶
Germanium	5.7x10 ⁻⁶
ZnSe	7.2x10 ⁻⁶

Lens Holder	TCE (1/°C)
Steel	9x10 ⁻⁶
Iron	$11 x 10^{-6}$
Aluminum	23x10 ⁻⁶
Brass	188x10 ⁻⁶

							_							_
Catalog:	SCHOTT.AGF	:					•	SCHOTT.	preferred. inqui	ry and ob	solete data s	ince 20	06. status	85
							_	K1:	1.03961212E	+000	D0:	1.8600)E-006	
Glass:	N-BAF52 N-BAK1						*	L1:	6.00069867E	-003	D1:	1.3100)E-008	
	N-BAK2 N-BAK4							K2;	2.31792344E	-001	D2:	-1.370	0E-011	
	N-BAK4HT													_
	N-BALF4 N-BALF5							L2:	2.00179144E	-002	EO:	4.3400)E-007	
	N-BASF2							K3:	1.01046945E	+000	E1:	6.2700)E-010	
	N-BASF64 N-BK10							L3:	1.03560653E	+002	Ltk:	1.7000)E-001	
	N-BK7 N-BK7HT						-				TCE:	7.1		
lename:	N-BK7										Temp:	20		1
ormula:	Sellmeier 1						-				p:	2.51		7
Status:	Preferred						-				dPaF:	-0.000	9	5
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	hermal Expansi Substitution	ion									_			_
	terial (Negativ	e Index)							N	1aximum \	Wavelength:	2.5000	00000	
/lelt Freq:	?	Comment:	step 0.5 available	2										
Rel Cost:	1	CR:	1	FR:	0	SI	R:	1	AR:	2.3		PR:	2.3	5
	Save Catalog	,	Insert	Glass			9	Sort By ->		Name:				-
Save Catalog As			Save Catalog As Cut Glass				Glass Report			Catalog		g Report		j
	Reload Catalo	yg 🖉	Copy Glass				Tr	Transmission		Compute		Nd/Vd		
Exit Paste Glass					Index Data			Fit Melt						

Material	Refractive Index at 4 µm	Refractive Index at 10 µm	<i>dn/dt/</i> °C	Comments
Germanium	4.0243	4.0032	0.000396	Expensive, large <i>dn/ dt</i>
Silicon	3.4255	3.4179*	0.000150	Large <i>dn/dt</i>
Zinc sulfide, CVD	2.2520	2.2005	0.0000433	
Zinc selenide, CVD	2.4331	2.4065	0.000060	Expensive, very low absorption
AMTIR I (Ge/As/SE:33/12/5	2.5141 5)	2.4976	0.000072	
Magnesium fluoride	1.3526	†	0.000020	Low cost, no ctg required
Sapphire	1.6753	Ť	0.000010	Very hard, low emissivity at high temperature

Zerodur Glass

Zerodur is extremely low expansion glass ceramic from Schott Company. It is used in high-tech applications:

- IC (Integrated Circuit)
- FPD (Flat Panel Display)
- Lithography
- High-precision metrology
- Astronomy (as mirror material)

CTE Grades	CTE (0 °C; 50 °C)*	
ZERODUR [®] Expansion Class 2	$0 \pm 0.100 \cdot 10^{-6}/K$	CTE is TCE
ZERODUR [®] Expansion Class 1	$0 \pm 0.050 \cdot 10^{-6}/K$	in Zemax
ZERODUR [®] Expansion Class 0	$0 \pm 0.020 \cdot 10^{-6}/K$	
ZERODUR [®] Expansion Class 0 SPECIAL	$0 \pm 0.010 \cdot 10^{-6}/K$	
ZERODUR [®] Expansion Class 0 EXTREME	$0 \pm 0.007 \cdot 10^{-6}/K$	
ZERODUR [®] TAILORED	upon request)	10^{-6} /K (± 0.010 \cdot 10 ⁻⁶ /K



Athermalization

ChatGPT says:

Athermalization is the process of designing a system or device in such a way that it <u>remains insensitive to changes in temperature</u>.

This can be achieved by various means, such as

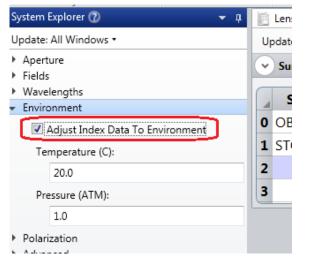
- using materials with low thermal expansion coefficients,
- incorporating compensating elements in the design, or
- using active control systems to regulate the temperature.

Athermalization is particularly important in precision instruments, such as **optical systems** and **electronic circuits**, where changes in temperature can cause drift or changes in performance. By designing these systems to be athermal, their performance can be maintained over a wide temperature range.

It is clear that, in design process, the optical system must be optimized to operate at different temperatures.

Thermal Analysis in Zemax

Zemax OpticStudio has thermal modeling capability. Before starting thermal analysis, you need to check "Adjust Index Data To Environment" option in System Explorer window.



In Zemax, Make Thermal Tool provides modelling thermal effects via MCE

ystem Project Scale plorer Preferences Lens	C Sequential	Lens Non-Sequentia Data	Field Data Cro Editor		Shaded Model Check Perfe		Window Options • Windows	Make Thermal Gonjugate Add All Data Previous
System	Mode	Editors	5	System Viewers	🖬 Diagnos	tics W	/indow Control	Configuration
tem Explorer 🕜	🔻 🕂 📄	Lens Data						Make Thermal
ate: All Windows 🔹	Up	odate: All Windows • 🛈	🕲 🕂 🔮 📖 🚽	½ ⅓ ≱ ₽ 9	ء 🗢 🌜 😂 单) 🔲 😫 🚧 🤿 🔞	1	Set up multiple configuration
perture elds		Surface 2 Properties () Configuration						design at different temperatu allow thermal variation of per
Vavelengths		Surface Type	Comment	Radius	Thickness	Material	Coating	to be analyzed
wironment 📝 Adjust Index Data To Env	0	OBJE(Standard •		Infinity	Infinity			No shortcut key assigned

Use Existing 3 Configurations	0
Delete Existing 3 Configurations	0
Number Of Configurations:	3 🗘
Minimum Temperature:	20
Maximum Temperature:	100
Sort By Surface:	

- All parameters that are affected by temperature have to be listed in the Multiple Configuration Editor (MCE).
- Thermal pickups are used for the parameters in the MCE so that those values are automatically computed by Zemax.
- Make Thermal tool provides convenient way to insert all operands in the MCE with thermal pickups.

Example1: Single Lens

Consider the lens

Glass:	BK7				
Object:	at infinity				
R ₁ :	+250 mm				
R ₂ :	-300 mm				
ct:	6 mm				
ENPD:	20 mm				
TCE:	7.1e-6 / °C				
Wavelength: d-line					

Investigate the temperature effects on the spot diagram and EFFL.

Use 4 different temperature configurations and let

$$T_{min} = -20 \text{ °C}$$

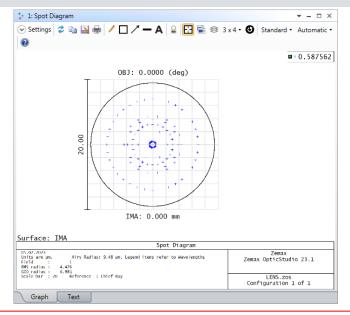
 $T_{max} = +60 \text{ °C}$

Example1: LDE

Initial LDE before Thermal Analysis:

B	Lens Data											-
Update: All Windows 🗸 🕐 🚱 💾 🦂 🤸 😵 🙀 🋊 🖆 🏦 🖄 🦃 🔘 O - <u>×</u> 🤝 💿 🔲 🔩 ↔ 🔿 🔞												
Surface 4 Properties Configu							onfiguration 1/1	$\langle \rangle$				
	Surfa	ace Type	Comment	Radius	Thickness	Material	Coating	Clear Semi-Di	a Chip Zone	Mech Semi-Dia	Conic	TCE x 1E-6
0	OBJECT	Standard 🔻		Infinity	Infinity			0.000	0.000	0.000	0.0	0.000
1	STOP	Standard 🔻		Infinity	0.000			10.000	J 0.000	10.000	0.0	0.000
2	(aper)	Standard 🔻		250.000	6.000	BK7		11.000	J 0.000	11.000	0.0	-
3	(aper)	Standard 🔻		-300.000	262.311			11.000	J 0.000	11.000	0.0	0.000
4	IMAGE	Standard 🔻		Infinity	-			6.981E-03	0.000	6.981E-03	0.0	0.000

After **Quick Focus** we have EFFL = 264.8459 mm RMS Spot Radius = 4.76 um Airy Disk Radius = 9.48 um



Example1: Make Thermal

File Setup Analyze (Optimize Toleranc	e Libraries Part D	esigner Prog	ramming STAR Help			
System Project Scale Explorer Preferences Lens	Sequential	Lens Non-Sequentia Data	Field Data Editor	Cross-Section	System Check	Bring To Front • Window Options • Windows	Make Thermal
System	Mode	Editors	G.	System Viewers	Diagnostics	Window Control	Configuration
System Explorer 🕜 🗾 👻 Lens Data							
Update: All Windows 🔹	U	pdate: All Windows 🔹 🛈	@ 🕂 🔮 📖	🏒 🔸 🏶 😫 🏶 🍘	0- 🛫 🧲 💿 📃 👙	++ ⇒ 🔞	Set up multiple configurations of the
 Aperture 	(~	Surface 2 Properties				Configurati	o design at different temperatures to
Fields						3	allow thermal variation of performance
 Wavelengths 		Surface Type	Commen	t Radius	Thickness M	aterial Coating	to be analyzed
 Environment 			connien			country	No sheeteet low assisted
Adjust Index Data To Environment O OBJEC Standard • Infinity Infinity							No shortcut key assigned

No Existing Configuration Data	0
Delete Existing Configuration Da	ita 🔘
Number Of Configurations:	4 🗘
Minimum Temperature:	-20
Maximum Temperature:	60
Sort By Surface:	

Example1: MCE Result of Analysis

TEMP:	Tempera	iture
PRES:	Pressure	
THIC:	Thicknes	S
CRVT:	Curvatur	e
GLSS:	Glass	
SDIA:	SemiDiar	neter
CHZN:	ChipZon	е
MCSD:	Mech. S	emiDiameter
Т	EFFL	SPOT

264.83

264.84

20.0 264.84 4.76

33.3 264.85 4.42

264.86

4.69

4.54

4.33

-20.0

6.6

60.0

~	Operand 14	4 Pro	operties 🔇	>)		Configur	atio	on 1/5 <	>)		
	Active : 1	./5	Config 1*	Config 2	2	Config 3		Config 4		Config 5	;
1	TEMP -	-	20.000	-20.000		6.667		33.333		60.000	
2	PRES -	-	1.000	1.000		1.000		1.000		1.000	
3	THIC 🕶	1	0.000	-6.885E-05	т	-2.294E-05	т	2.294E-05	т	6.881E-05	•
4	CRVT -	2	4.000E-03	4.001E-03	Т	4.000E-03	Т	4.000E-03	Т	3.999E-03	•
5	THIC •	2	6.000	5.998	т	5.999	т	6.001	т	6.002	•
6	GLSS 🕶	2	BK7	BK7	Ρ	BK7	Ρ	BK7	Ρ	BK7	1
7	SDIA 🕶	2	11.000	10.997	т	10.999	Т	11.001	Т	11.003	•
8	CHZN 🔻	2	0.000	0.000	т	0.000	Т	0.000	т	0.000	
9	MCSD 🕶	2	11.000	10.997	Т	10.999	т	11.001	т	11.003	
10	CRVT •	3	-3.333E-03	-3.334E-03	т	-3.334E-03	т	-3.333E-03	т	-3.332E-03	•
11	THIC -	3	262.311	262.311	Т	262.311	Т	262.311	Т	262.311	•
12	SDIA 🕶	3	11.000	10.997	т	10.999	Т	11.001	Т	11.003	
13	CHZN 🔻	3	0.000	0.000	т	0.000	т	0.000	т	0.000	•
14	MCSD -	3	11.000	10.997	Т	10.999	т	11.001	Т	11.003	ŀ

Example2: Thermal Analysis of a Mirror

Consider a concave mirror made from aluminum.

|R| = 500 mmENPD = 100 mm TCE = 23e-6 / °C Conic = -1 (parabolic mirror)

Investigate the temperature effects on radius and semi-diameter, at T = 20 °C and at T = +60 °C.

We have two configurations:

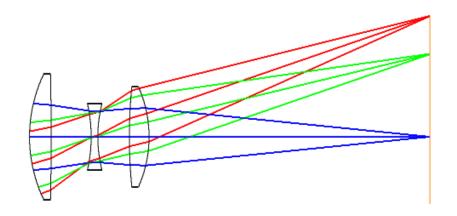
 ✓ Surface ∃ 	Properties 🔇	\diamond		Configuration	n 1/1 🕜 📎		
Surf	асе Туре	Comme	Radius	Thickness	Material	TCE x 1E-6	Conic
OBJECT	Standard 🕶		Infinity	Infinity		0.000	0.000
1 STOP	Standard 🕶		Infinity	300.000		0.000	0.000
2	Standard 🕶		-500.000	-250.000	MIRROR	23.000	-1.000
3 IMAGE	Standard 🕶		Infinity	-		0.000	0.000
Lens Data		•					▼ - □
Update: All Wi	indows • 🕐 🛞		⊀ ⊀ \$ ⊉ ₽ (\$ ** • ? n 2/2 < >		▼ - □
Update: All Wi	Properties	+ • 1	<mark>⊀ ⊀ ≹ ⊉ ‡</mark> Radius	0 ≰ ፍ 💿 🗉		TCE x 1E-6	✓ – □
Update: All Wi		+ • 🛍		O 💇 Ϛ 💿 🗐	n 2/2 🔇 🔊	TCE x 1E-6 0.000	
Update: All Wi Surface 3	Properties <	+ • 🛍	Radius	O S Configuration	n 2/2 🔇 🔊		Conic
Update: All Wi Surface 3 Surf ODBJECT	B Properties Comparent Co	+ • 🛍	Radius Infinity	O 🔮 Ϛ 💿 🗐 Configuration Thickness Infinity	n 2/2 🔇 🔊	0.000	Conic 0.000

	Multi-Con odate: All V	Vindows	on Editor	0		: د ج
•	Operand	8 Prop	erties 🔇 (C	onf	iguration 1/2	<
	Active	: 1/2	Config 1*	,	Config 2	
1	TEMP •	r _	20.000		60.000	
2	PRES •	· -	1.000		1.000	
3	THIC	· 1	300.000		299.998	Т
4	CRVT •	· 2	-2.000E-03		-1.998E-03	Т
5	THIC	· 2	-250.000		-250.230	Т
6	SDIA •	· 2	50.000		50.046	Т
7	CHZN •	· 2	0.000		0.000	Т
8	MCSD •	2	50.000		50.046	Т

Example3: Thermal Analysis of a CookeTriplet

In this example, we will investigate the Cooke Triplet at: <zemax>\Samples\Sequential\Objectives\Cooke 40 degree field.zos

Surface 7 Pr	operties 🔇								Configuratio	n 1/1 < 📎	
Surfac	се Туре	Com	Radius	Thickness	Material	Coating	Clear Semi-D	Chip Zone	Mech Semi-E	Conic	TCE x 1E-6
OBJECT	Standard 🔻		Infinity	Infinity			Infinity	0.000	Infinity	0.000	0.000
1 (aper)	Standard 🔻		22.014 V	3.259 V	SK16 S	AR	9.500 U	0.000	9.500	0.000	-
2 (aper)	Standard 🔻		-435.760 V	6.008 V		AR	9.500 U	0.000	9.500	0.000	23.600
3 (aper)	Standard 🔻		-22.213 V	1.000 V	F2 S	AR	5.000 U	0.000	5.000	0.000	-
4 STOP (aper)	Standard 🔻		20.292 V	4.750 V		AR	5.000 U	0.000	5.000	0.000	23.600
5 (aper)	Standard 🔻		79.684 V	2.952 V	SK16 S	AR	7.500 U	0.000	7.500	0.000	-
6 (aper)	Standard 🔻		-18.395 V	42.208 V		AR	7.500 U	0.000	7.500	0.000	23.600
7 IMAGE	Standard 🔻		Infinity	-			18.173	0.000	18.173	0.000	0.000



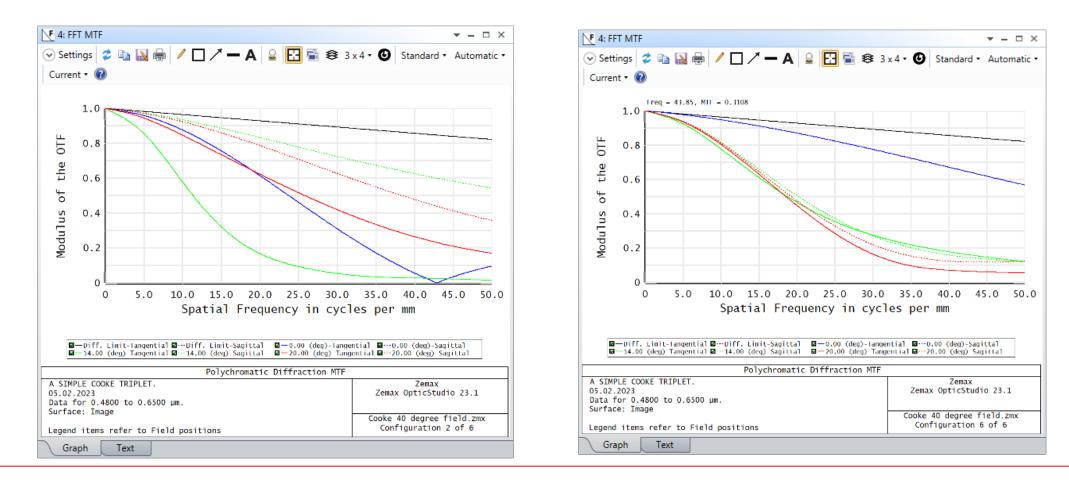
Lens holder: Aluminum EFFL = 50 mm F/# = 5FOV = 40° $\lambda = [0.48, 0.55, 0.65]$ nm

T = ±50 °C

No Existing Configuration Data	0
Delete Existing Configuration Dat	a 🔘
Number Of Configurations:	5 🗘
Minimum Temperature:	-50
Maximum Temperature:	50
Sort By Surface:	

E) N	Multi-Configu	urati	ion Editor									· -		3
Upo	date: All Win	dow	s • 🔪 🕹 🗡	o 🖲 🕷 🖬	Ľ	💿 🗧 ·	••	-> 🔞						
•	Operand 20	Pro	operties 🔇 🔉				Co	nfiguration 5	/6	< >				
	Active : 5	/6	Config 1	Config 2		Config 3		Config 4		Config 5	ł	Config 6	;	Γ
1	TEMP 🔻	-	20.000	-50.000		-25.000		0.000		25.000		50.000		
2	PRES 🔻	-	1.000	1.000		1.000		1.000		1.000		1.000		
3	CRVT 🕶	1	0.045	0.045	Т	0.045	Т	0.045	т	0.045	т	0.045	Т	
4	THIC 🕶	1	3.259	3.258	Т	3.258	Т	3.259	Т	3.259	Т	3.260	Т	
5	GLSS 🕶	1	SK16	SK16	Ρ	SK16	Ρ	SK16	Ρ	SK16	Ρ	SK16	Ρ	l
6	SDIA 🕶	1	9.500	9.496	Т	9.497	т	9.499	т	9.500	Т	9.502	Т	
7	CHZN 🔻	1	0.000	0.000	Т	0.000	т	0.000	т	0.000	Т	0.000	Т	
8	MCSD 🔻	1	9.500	9.496	Т	9.497	т	9.499	т	9.500	Т	9.502	Т	
9	CRVT -	2	-2.295E-03	-2.296E-03	Т	-2.295E-03	т	-2.295E-03	т	-2.295E-03	т	-2.294E-03	Т	
10	THIC 🕶	2	6.008	5.997	Т	6.001	т	6.005	Т	6.008	Т	6.012	Т	
11	SDIA 🕶	2	9.500	9.496	Т	9.497	т	9.499	т	9.500	т	9.502	Т	
12	CHZN 🔻	2	0.000	0.000	Т	0.000	т	0.000	Т	0.000	Т	0.000	Т	
13	MCSD 🗸	2	9.500	9.496	т	9.497	Т	9.499	т	9.500	т	9.502	Т	

Look into MTF, OPD, RMS vs Field, RMS vs Wavelength, Ray Fan plots. You will see effects temperature on the design clearly.



Example3: Athermalization

To Make system athermal,

- Setup all CRVT ve GLSS operand as variable in Config 1.
- For all configurations, at surface 6, all THIC operands must be variable. This is required to get minimum spot radius for all configurations.

	Active : 1	1/6	Config 1*	•	Config 2		Config 3	;	Config 4		Config 5		Config 6	
1	TEMP 🔻	-	20.000		-50.000		-25.000		0.000		25.000		50.000	
2	PRES -	-	1.000		1.000		1.000		1.000		1.000		1.000	
3	CRVT 🕶	1	0.045	v	0.045	т								
4	THIC 🕶	1	3.259		3.258	т	3.258	Т	3.259	т	3.259	Т	3.260	т
5	GLSS 🔻	1	SK16		SK16	Ρ	SK16	Ρ	SK16	Ρ	SK16 F	Р	SK16	Ρ
6	SDIA 🕶	1	9.500		9.496	т	9.497	т	9.499	т	9.500	Т	9.502	Т
7	CHZN 🔻	1	0.000		0.000	т								
8	MCSD 🕶	1	9.500		9.496	т	9.497	т	9.499	т	9.500	Т	9.502	Т
9	CRVT -	2	-2.295E-03	V	-2.296E-03	т	-2.295E-03	т	-2.295E-03	т	-2.295E-03	Т	-2.294E-03	Т
10	THIC -	2	6.008		5.997	т	6.001	т	6.005	т	6.008	Т	6.012	Т
11	SDIA 🕶	2	9.500		9.496	т	9.497	т	9.499	т	9.500	Т	9.502	Т
12	CHZN 🔻	2	0.000		0.000	т								
13	MCSD 🔻	2	9.500		9.496	Т	9.497	Т	9.499	Т	9.500	Т	9.502	Т
14	CRVT 🕶	3	-0.045	V	-0.045	Т								
15	THIC -	3	1.000		0.999	Т	1.000	Т	1.000	Т	1.000	Т	1.000	Т
16	GLSS 🔻	3	F2		F2	Ρ	F2	Ρ	F2	Ρ	F2 F	Ρ	F2	Ρ
17	SDIA 🕶	3	5.000		4.997	Т	4.998	Т	4.999	т	5.000	Т	5.001	Т
18	CHZN 🔻	3	0.000		0.000	Т								
19	MCSD 🔻	3	5.000		4.997	Т	4.998	Т	4.999	Т	5.000	Т	5.001	Т
20	CRVT 🔻	4	0.049	۷	0.049	Т	0.049		0.049	Т	0.049		0.049	Т
21	THIC -	4	4.750		4.742	Т	4.745	Т	4.748	Т	4.751	Т	4.754	Т
22	SDIA 🔻	4	5.000		4.997	Т	4.998	Т	4.999	Т	5.000	Т	5.001	Т
23	CHZN 🔻	4	0.000		0.000	Т								
24	MCSD 🕶	4	5.000		4.997	Т	4.998	Т	4.999	Т	5.000 1	Т	5.001	Т
25	CRVT -	5	0.013	V	0.013		0.013		0.013		0.013	Т	0.013	
26	THIC -	5	2.952		2.951		2.951		2.952		2.952		2.953	
27	GLSS 🔻	5	SK16		SK16		SK16		SK16		SK16 F		SK16	
28	SDIA 🔻	5	7.500		7.497		7.498		7.499		7.500		7.501	
_	CHZN -	5	0.000		0.000		0.000		0.000		0.000		0.000	
	MCSD -	5	7.500		7.497		7.498		7.499		7.500		7.501	
_	CRVT -	6	-0.054		-0.054								-0.054	
32		6	42.208	V	42.140						42.213		42.237	
33		6	7.500		7.497		7.498				7.500		7.501	
	CHZN -	6	0.000		0.000		0.000		0.000		0.000		0.000	_
35	MCSD 🔻	6	7.500		7.497	Т	7.498	Т	7.499	Т	7.500	Г	7.501	T

Example3: MFE

Select Spot for Image Quality and press OK.

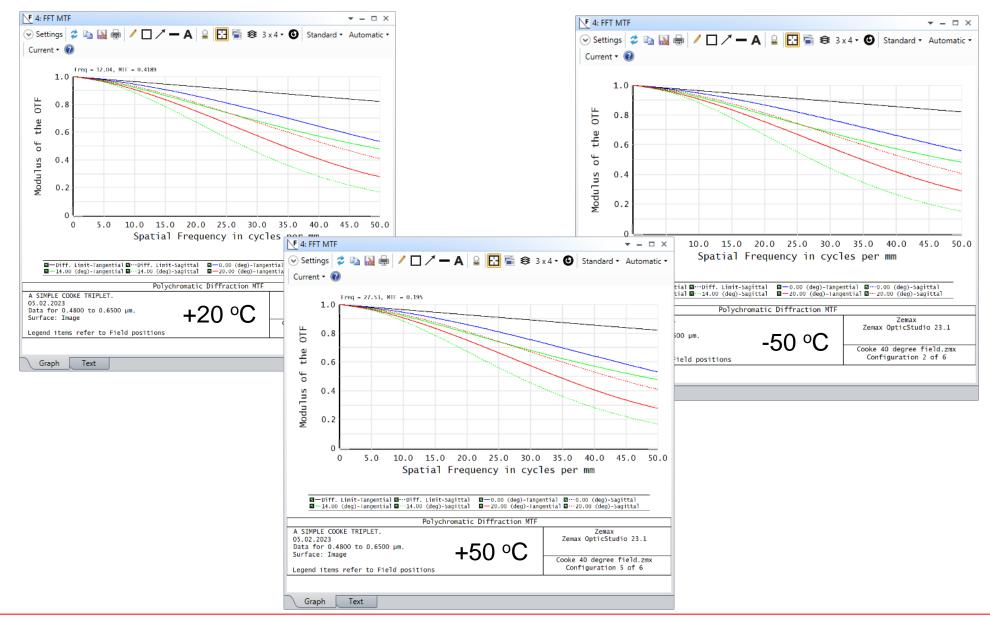
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Optimization Wizard Current Operand (2)	Optimization Function Image Quality: Spatial Frequency: X Weight: Y Weight: Type:	Spot • 30 1 1 1 RMS •	Pupil Integrat Gaussian C Rectangula Rings: Arms: Obscuration:	Quadrature
	Reference: Max Distortion (%): Ignore Lateral Color Optimization Goal Best Nominal Perform Improve Manufactur Weight: 1	mance	Start At: Overall Weigh	nt: 1
	OK Apply	Close		

Set EFFL = 50 mm.

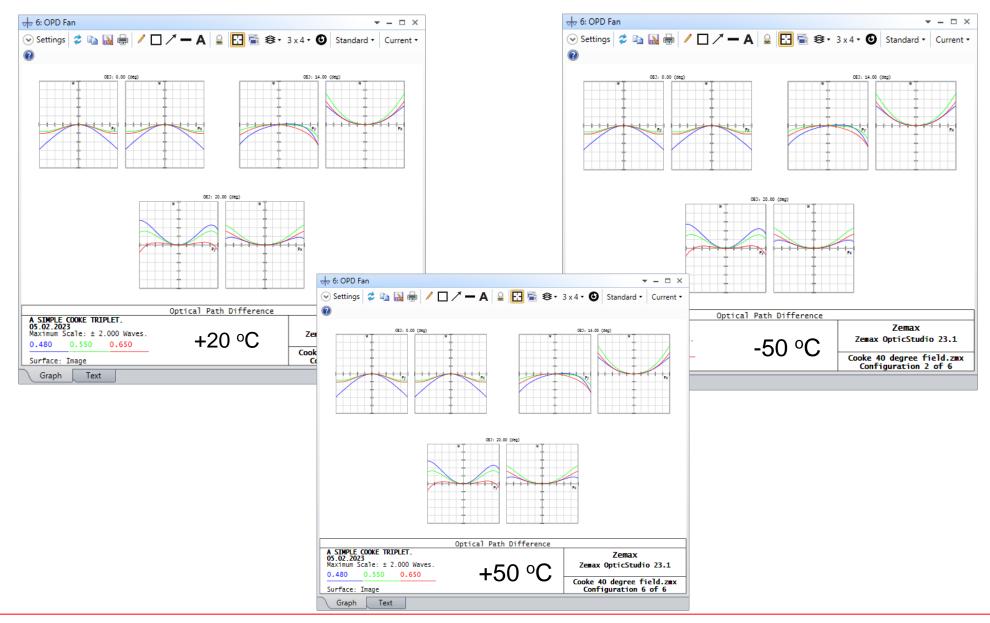
2	🔚 🚺 👌	X 🛠 💿	S O	5*	• 🔿 (2)							
•	Wizards a	nd Operands		\mathbf{D}			Me	erit Fu	nctio	on: 0.008	338464725	379272	
	Туре		Wave							Target	Weight	Value	% Contrib
1	CONF 🕶	1											
2	EFFL 🔻		2							50.000	1.000	0.000	0.000
3	DMFS -												
4	BLNK -	Sequential r	merit fui	nction	RMS	spot x	+y cen	troid	хw	gt = 1.00	00 Y Wgt	= 1.0000 G	Q 3 rings 6 a
5	CONF 🕶	1											
6	BLNK 🕶	No air or gla	ass cons	traints	5.								
7	BLNK -	Operands fo	or field 1	L.									
8	TRCX -		1	0.000	0.000	0.336	0.000			0.000	0.078	5.434E-03	0.100
9	TRCY -		1	0.000	0.000	0.336	0.000			0.000	0.078	0.000	0.000
•	TRCX -		1	0.000	0.000	0.707	0.000			0.000	0.124	4.222E-03	0.096
-			1	0.000	0.000	0.707	0.000			0.000	0.124	0.000	0.000
10	TRCY -		-							0.000	0.078	-8.163E-04	2 2505 02
10 11	TRCY - TRCX -			0.000	0.000	0.942	0.000			0.000	0.076	-0.103L-04	2.250E-03
10 11 12 13			1			0.942				0.000	0.078	0.000	2.250E-03 0.000

In **Optimize** Tab, click on **Hammer Current** and wait a few minutes. You will see the decrease of thermal effects on the system.

Example3: Athermalization (MTF plot)



Example3: Athermalization (OPD)



Example3: Athermalization (Result)

<u> </u>	EFFL (mm)	TOTR (mm)
-50	50.06	60.64
-25	50.04	60.61
0	50.02	60.59
+20	50.00	60.58
+25	50.00	60.57
+50	49.97	60.55
	Δf=90 μm	ΔL=90 μm

At 20 °C, depth of focus is $\delta = \pm 27.5 \ \mu m$.

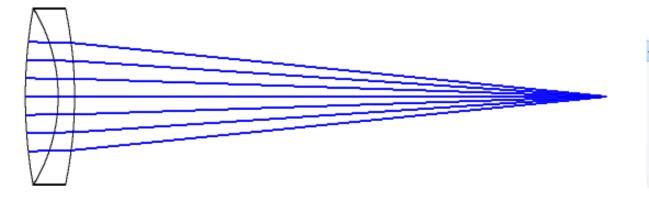
Since $\Delta L/2 > \delta$, we may need manual or auto focus system.

Remember, one way to make a system athermal is to translate (move) lens elements by a greater or lesser amount depending on the magnification.

Example4: Athermal Doublet Design

In this example we will design an <u>athermal doublet</u> whose LDE is as follows at 20 °C. We want to design it such that the optical performases are almost the same at 20 °C and 100 °C.

	Surface Type	Comment	Radius		Thickness	;	Material		Coating	Clear Semi	-D
0	OI Standard 🕶		Infinity		Infinity					0.000	
1	ST Standard 🔻		92.847	V	6.000		BK7	S		16.000	υ
2	(a Standard 🔻		-30.716	V	3.000		F2	S		16.000	U
3	(a Standard 🔻		-78.197	٧	97.360	٧				16.000	U
4	IN Standard ▼		Infinity		-					0.010	



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Aperture Type:									
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Aperture Value:									
20.0									
Apodization Type:									
Uniform									
Clear Semi Diameter Margin Millimeters:									
0.0									
Clear Semi Diameter Margin %									
0.0									
Global Coordinate Reference Surface									
1									
Telecentric Object Space									
Afocal Image Space									
Iterate Solves When Updating									
Fast Semi-Diameters									
Check GRIN Apertures									
 Fields Wavelengths 									
Wavelengths Settings									
Wavelength 1 (0.486 um, Weight = 1.000)									
 Wavelength 2 (0.589 um, Weight = 1.000) Wavelength 3 (0.656 um, Weight = 1.000) 									
· Wavelength 5 (0.050 dill, Weight = 1.000)									

Multi-Configuration Editor											
Update: All Windows 🔹 🔖 🖓 🗡 🖂 🎒 💷 🧲											
✓ Operand 13 Properties < >											
	Active :	1/2	Config 1*		Config 2						
1	TEMP 🔻	-	20.000		100.000						
2	PRES -	-	1.000		1.000						
3	CRVT -	1	0.011	V	0.011	т					
4	CRVT -	2	-0.033	۷	-0.033	Т					
5	CRVT -	3	-0.013	۷	-0.013	Т					
6	THIC •	1	6.000		6.003	Т					
7	THIC -	2	3.000		3.002	Т					
8	THIC -	3	97.360	۷	97.361	Т					
9	GLSS -	1	BK7	S	BK7	Ρ					
10	GLSS -	2	F2	S	F2	Ρ					
11	SDIA •	1	16.000		16.009	т					
12	SDIA •	2	16.000		16.010	Т					
13	SDIA 🕶	3	16.000		16.010	Т					

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1	CONF -	1												*
2	EFFL 🔻		2							100.000	1.000	100.000	1.983E-09	=
3	GTCE 🕶	1								0.000	0.000	7.100	0.000	
4	GTCE 🕶	2								0.000	0.000	8.200	0.000	
5	DIFF 🔻	3	4							0.000	0.000	-1.100	0.000	
6	ABSO 🔻	5								0.000	0.000	1.100	0.000	
7	OPLT 🔻	6								1.000	1.000	1.100	19.825	
8	DMFS -													
9	BLNK 🕶	₩ ▼ Default merit function: RMS wavefront centroid GQ 3 rings 6 arms												
10		1												-

EFFL: Effective Focal Length

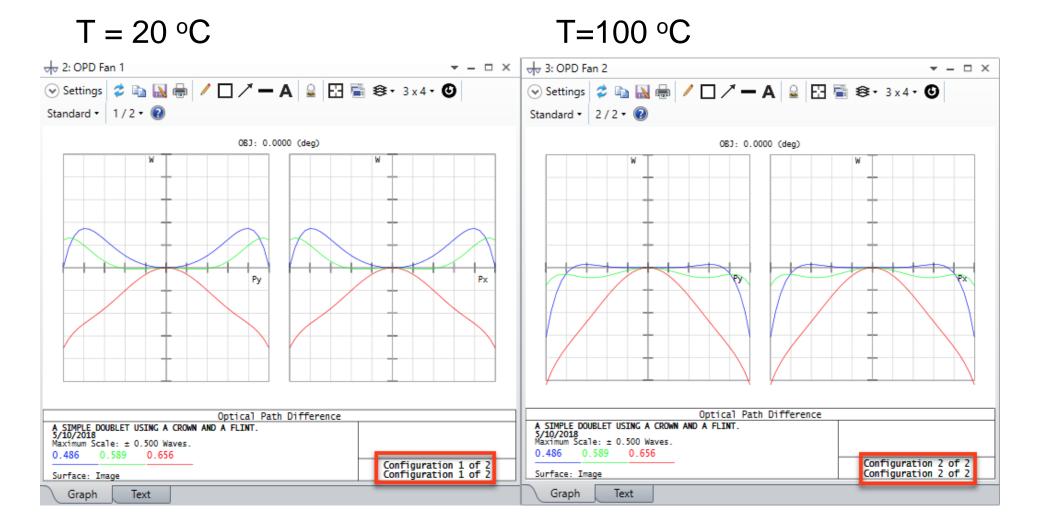
GTCE: Glass TCE value

DIFF: Difference between operands

ABSO: Absoute Value

OPLT: Operand Less Than

Example4: OPD Before Optimization



Example4: OPD After Optimization

