

# Introduction

## Modelling of Optotune's tunable lenses in Zemax

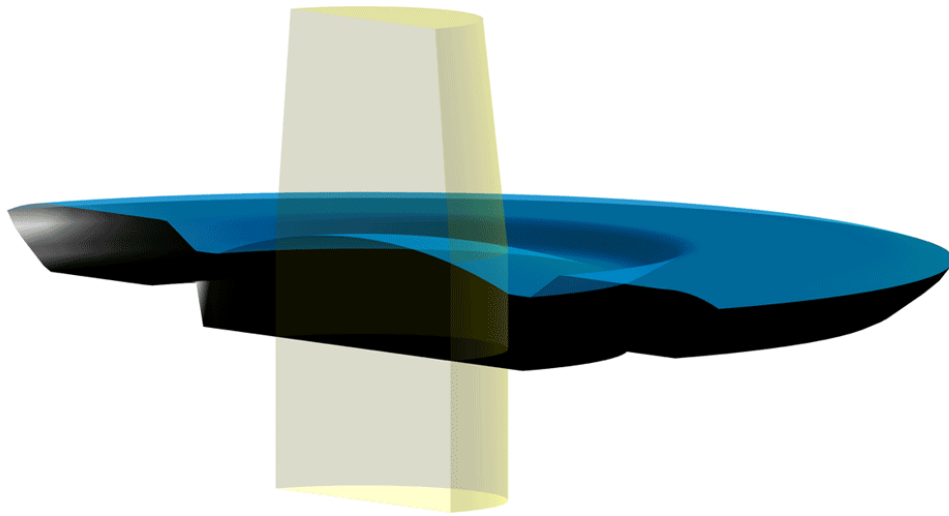
Dietikon, January 2016

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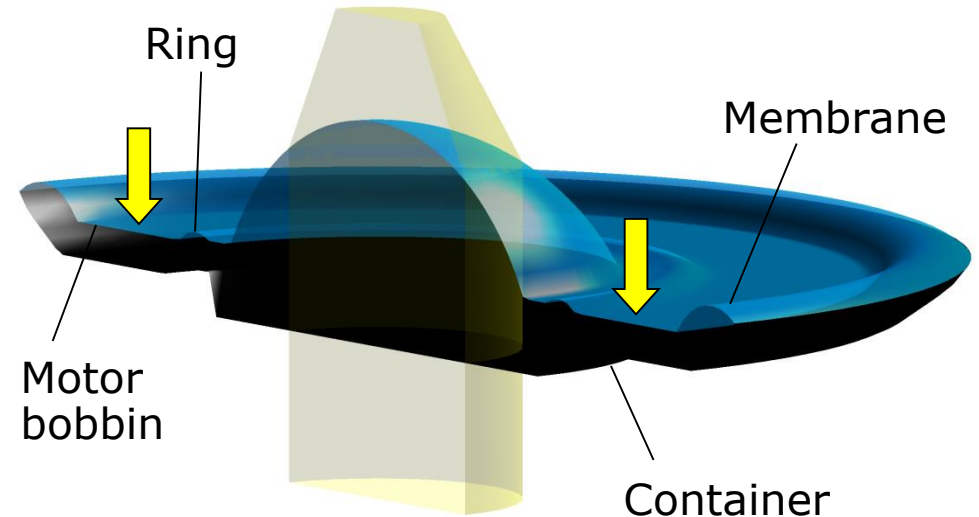
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# Actuation principle of Optotune's electrically tunable lenses

Passive state (0 mA current)



Active state (e.g. 300 mA current)



- The electrically tunable lenses from Optotune are shape-changing lenses. The core of the lens consists of a container, which is filled with an optical fluid and sealed off with an elastic polymer membrane.
- An electromagnetic actuator is integrated in the lens which controls a ring that exerts pressure on the container and squeezes more liquid into the lens volume. This leads to a bulging of the membrane.
- Therefore, the focal length of the lens can be controlled by the current flowing through the coil of the actuator.

Videos are available on [www.optotune.com](http://www.optotune.com)

Note: Animation for illustration purpose only. Proportions and degrees of deflection can vary.

# Example of Zemax modelling

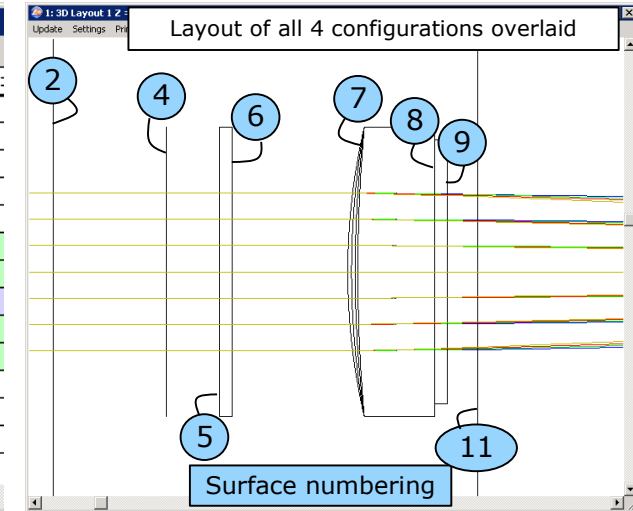
**Lens Data Editor: Config 4/4**

Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic	Pa
OBJ	Standard		Infinity	Infinity		0.0000	0.0000	
STO	Standard		Infinity	10.0000		3.0000	U	0.0000
2	Standard	Housing	Infinity	0.0000		15.0000	U	0.0000
3*	Standard		Infinity	4.3000		7.0000	U	0.0000
4*	Standard	Holder ring	Infinity	2.0000		5.5000	U	0.0000
5*	Standard	Cover glass f..	Infinity	0.5000	BK7	5.5000	U	0.0000
6*	Standard	Cover glass b..	Infinity	4.3714	E	5.5000	U	0.0000
7*	Standard	Adaptive surf..	24.3752	3.2786	OL1024_UV_VIS_NIR	5.5000	U	0.0000
8*	Standard	Container gla..	Infinity	0.5000	BK7	5.0000	U	0.0000
9*	Standard	Container gla..	Infinity	1.1500		5.0000	U	0.0000
10*	Standard		Infinity	0.0000		5.0000	U	0.0000
11	Standard	Housing	Infinity	76.9230	M	15.0000	U	0.0000
IMA	Standard		Infinity	-		5.0000	U	0.0000

**Annotations:**

- 1**: Adaptive (tunable) surface
- 2**: Non-optical surfaces are modelled if they indicate dimensions or FOV-relevant apertures of the lens

Glass model of optical liquid (included in Optotune's .AGF glass catalog)



The multi-configuration editor allows toggling between the different focus states (curvatures of the adaptive surface) of the lens. The configurations correspond to different actuation currents.

**Multi-Configuration Editor**

Active	Config 1	Config 2	Config 3	Config 4*
1: MOFF	0	No current	Max EL-E-4	Abs. Max
2: CRVT	7	0.0163	0.0230	0.0320

Edge thickness solves are used for modelling the fact, that Optotune lenses have a moving vertex and a fixed lens edge defined by the so called lens shaper

**Thickness solve on surface 6** **1**

Solve Type: Edge Thickness

Thickness: 5

Radial Height: 5.5

OK Cancel

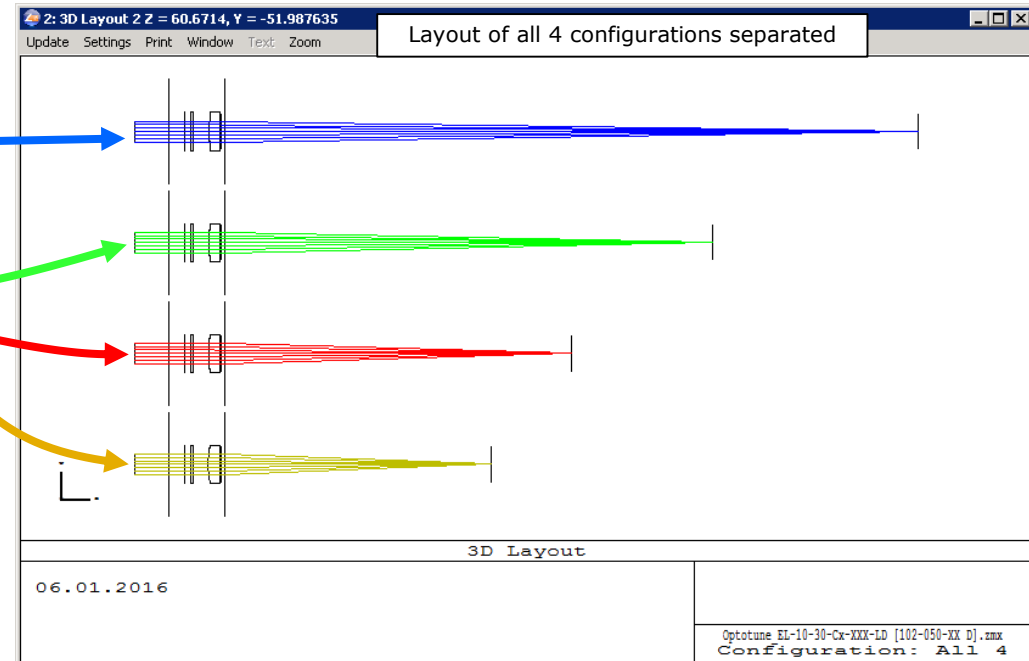
**Thickness solve on surface 7** **2**

Solve Type: Edge Thickness

Thickness: 2.65

Radial Height: 5.5

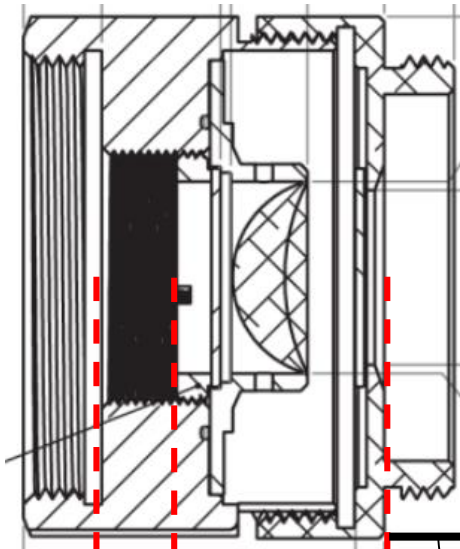
OK Cancel



# Datasheet values and Zemax model

## Layout

Mechanical layout

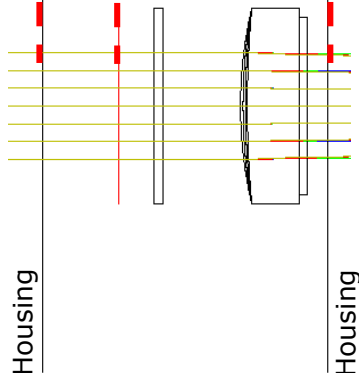


Note: Tuning range in data sheet is specified as back flange focal length/power (BFFL/BFFP) and measured from here

Note: Non-optical surfaces are modelled in Zemax if they indicate the outer dimensions or field-of-view-relevant apertures of the lens.

Note: The surfaces named 'Housing' in the Zemax Lens Data Editor define the boundary surfaces from where on you can modify the Optotune model in order to embed the Optotune lens in your system.

Optical layout



## Focus states

Tuning range from datasheet

Overview of available standard products

Standard products	Tuning range <sup>2</sup>	Refractive index	Cover glass coating	RMS wave-front error <sup>3</sup>	Integrated offset lens	Temperature sensor
EL-10-30-VIS-LD	+8.3 to +19.9 dpt	1.30	400 – 700 nm	<0.50 $\lambda$	No	No
EL-10-30-NIR-LD	+8.3 to +19.9 dpt	1.30	700 – 1100 nm	<0.50 $\lambda$	No	No
EL-10-30-VIS-HR	+16.5 to 44.5 dpt	1.56	400 – 700 nm	<0.50 $\lambda$	No	No
EL-10-30-C-VIS-LD	+5 to +10 dpt	1.30	400 – 700 nm	<0.25 $\lambda$	No	Yes
EL-10-30-C-NIR-LD	+5 to +10 dpt	1.30	700 – 1100 nm	<0.25 $\lambda$	No	Yes

Membrane curvatures in Zemax Multi-Configuration Editor

Multi-Configuration Editor					
Edit Solve Tools View Help					
Active : 4/4	Config 1	Config 2	Config 3	Config 4*	
1: MOFF	0	No current	Any current	Max EL-E-4	Abs. Max
2: CRVT	7	0.0163	0.0230	0.0320	0.0410

Back flange focal length as indicated in Zemax

Infinity	0.5000	E
Infinity	1.1500	
Infinity	0.0000	
Infinity	200.0000	M
Infinity	-	

Infinity	0.5000	B
Infinity	1.1500	
Infinity	0.0000	
Infinity	100.0000	M
Infinity	-	



# Relation between current, curvature & optical power



## Example for two lens types



	EL-10-30-Ci-VIS-LD			EL-16-40-TC-VIS-5D					Unit	Relation
	No current	Max EL-E-4	Abs. Max	Abs. Min	Min EL-E-4	No current	Max EL-E-4	Abs. Max		
Current	0	250	400	-500	-250	0	250	500	mA	
Curvature	0.017	0.033	0.043	-0.015	-0.007	0.002	0.010	0.018	1/mm	1/r
Radius	60.0	30.0	23.1	-66.7	-150.0	600.0	100.0	54.5	mm	$f*(n-1)$ , $1/c$
Focal length	200	100	77	-222	-500	2'000	333	182	mm	$r/(n-1)$ , $1/OP$
Optical power	5.0	10.0	13.0	-4.5	-2.0	0.5	3.0	5.5	Dpt	1/f

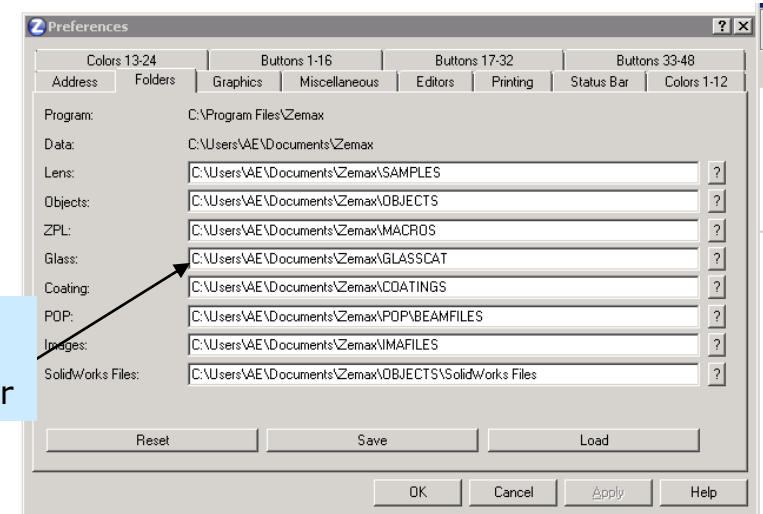
### Note:

- EL-10-30-Ci-VIS-LD-MV achieves -1.5 to +3.5 Dpt by adding a -150mm (-6.67 Dpt) offset lens to the EL-10-30-Ci-VIS-LD

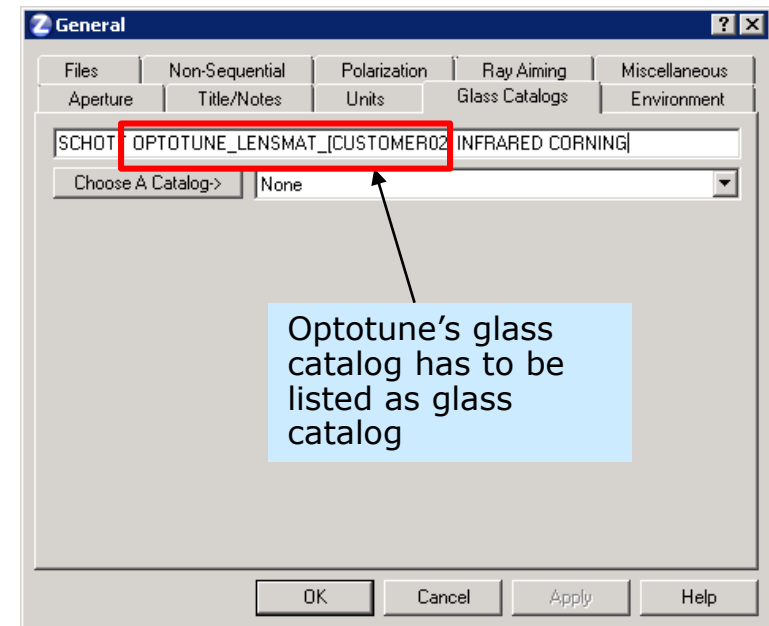
# Troubleshooting: Optical material is missing in Zemax

- The required glass catalog is called "OPTOTUNE\_LENSMAT\_[CUSTOMER02].AGF"
- Check Zemax preferences for correct file location

Optotune's glass catalog has to be copied into this folder



- Check in Zemax -> General that Optotune's catalog is listed
- Note the empty space between the different catalogs



# Troubleshooting: Optical material is missing in Zemax



- As an example, the OL1024\_UV\_VIS\_NIR material is listed correctly (red box)

Lens Data Editor: Config 3/3

Surf	Type	Comment	Radius	Thickness	Glass	Semi-Diameter	Conic
OBJ	Standard		Infinity	Infinity		0.0000	0.0000
ST0	Standard		Infinity	10.0000		2.5000 U	0.0000
2	Standard	Housing entrance aperture	Infinity	2.8000		6.3500 U	0.0000
3*	Standard	Offset lens	-91.700	1.5000	F_SILICA	6.3500 U	0.0000
4*	Standard		Infinity	1.1500		6.3500 U	0.0000
5*	Standard	Container glass	Infinity	0.5000	N-BK7	6.0000 U	0.0000
6*	Standard		Infinity	2.7523 E	OL1024_UV_VIS_NIR	5.0000 U	0.0000
7*	Standard	Adaptive surface	-43.103	4.2477 E		5.5000 U	0.0000
8	Standard	Housing intermed aperture	Infinity	12.4300		5.5000 U	0.0000
9#	Standard	Glass plate	Infinity	0.5000	N-BK7	12.7000 U	0.0000
10#	Standard		Infinity	14.8000		12.7000 U	0.0000
11	Standard	Housing exit aperture	Infinity	21.0000		14.0000 U	0.0000
IMA	Standard		Infinity	-		5.0000 U	0.0000

- All glass materials are listed in the glass catalog
- The glass catalog can be opened with a standard text editor
- You can double check directly in the file if the required glass exists (e.g. OL1042\_UV\_VIS\_NIR)

OPTOTUNE\_LENSMAT [CUSTOMER02]AGF - Notepad

```

CC OL1224_VIS 2 0 1.291156 108.462415 0 0 0
GC
ED 0.00000000E+000 0.00000000E+000 1.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
CD -5.79999304E+004 0.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
IT 3.800000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
IT 8.800000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
NM OL1129_VIS_NIR 2 0 1.382272 64.799910 0 0 0
GC
ED 0.00000000E+000 0.00000000E+000 1.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
CD 9.88417343E+001 8.49958325E-002 4.45886098E-004 1.49210194E-001 5.08780697E+004 1.84523836E+007
IT 4.000000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
IT 1.600000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
NM OL1114_VIS 1 0 1.301113 101.163001 0 0 0
GC
ED 0.00000000E+000 0.00000000E+000 1.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
CD 1.78743411E+000 -6.46839577E-002 -5.86654592E-002 1.68683405E-002 -2.08497607E-003 9.51239825E-005
IT 4.000000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
IT 7.065000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
NM OL1042_UV_VIS_NIR 1 0 1.300218 101.344258 0 0 0
GC
ED 0.00000000E+000 0.00000000E+000 1.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
CD 1.69308880E+001 1.07440632E-001 8.36034147E-001 2.95769232E-002 -3.38397675E+003 2.34217755E+006
IT 4.000000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
IT 7.065000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
NM OL0902_UV_VIS_NIR 2 0 1.558720 20.275910 0 0 0
GC
ED 0.00000000E+000 0.00000000E+000 1.00000000E+000 0.00000000E+000 0.00000000E+000 0.00000000E+000
CD 1.47378404E+001 1.78028961E-001 8.36034147E-001 2.95769232E-002 -3.38397675E+003 2.34217755E+006
IT 4.000000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000
IT 7.065000E-001 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000 1.000000E+000

```

OL1042\_UV\_VIS\_NIR, among others, is listed as a glass



# Troubleshooting: Optical material is missing in Zemax

- When using older Zemax versions, the encoding can be important
- Check in Zemax preferences what encoding is used

