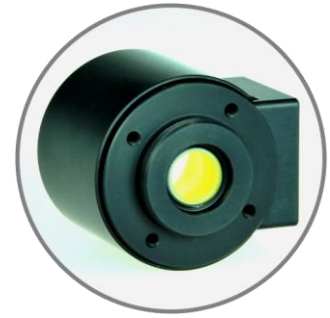


## Electrically Tunable Lens EL-10-42-OF

The working principle of EL-10-42-OF lens with integrated optical feedback is based on the well-established shape-changing flexible lens. The curvature of the lens is adjusted by applying an electrical current. The focal length is accordingly tuned to a desired value within milliseconds. The EL-10-42-OF has an integrated optical feedback, measuring the optical power of the lens in real-time. Optimal control is guaranteed using the EL-E-OF-A analog driver board or Optotune-DSD digital driver board developed by SCAPS GmbH. This makes EL-10-42-OF suitable for laser marking and engraving applications.



### Main specifications

Product	EL-10-42-OF-1064	EL-10-42-OF-1064-S (SCAPS)	
Clear aperture	10		mm
Focal length	-500 to +500	-555 to +555	mm
Optical power: tuning range	-2.0 to +2.0	-1.8 to +1.8	dpt
Optical power: pointing stability (+/- STD)	< +/- 0.002		dpt
Optical power: repeatability (+/- STD)	< +/- 0.010		dpt
Optical power: long term stab. 8h (+/- STD)	< +/- 0.020 <sup>1</sup>		dpt
Lateral spot shift over full tuning range	< 45		µRad
Lateral long term drift at fixed focal length	< 5		µRad
Wavefront error	< 0.25 @ 525 nm		λ RMS
Transmission	> 95% @ 1064 nm		
Long term radiation damage @ 1064 nm: 40 mJ/cm <sup>2</sup> at 20 kHz	No effect after 2000 h		
Damage threshold <sup>2</sup> @ 1064 nm: 125 ns-pulsed at 50 kHz 10 ps-pulsed at 50 kHz	2.6 2.05		J/cm <sup>2</sup>
Response time Controlled with EL-E-OF-A analog board	80% step: 12 20% step: 6		ms
Response time Controlled with Optotune-DSD digital board		80% step: 8 20% step: 4.5	ms
Tracking delay Controlled with Optotune-DSD digital board		< 2	ms
Focal length resolution	Continuous (depends on control electronics)		
Lifecycles (10%-90% sinusoidal)	> 1'000'000'000		
Weight	90		g
Heater set temperature	47		°C
Operating temperature	10 to 40		°C
Storage Temperature	-20 to 80		°C

### Parameters in combination with f = 160 mm f-theta lens<sup>3</sup>

Max z-tuning range in a marking system	100	90	mm
Repeatability (10%-90% step)	< 250		µm
Long term drift over 8h	< 500		µm

### Electrical specifications

Max lens power consumption	1.5	W
Max lens current	385	mA
Max heater power consumption	12	W
Heater resistance @ 25°C	25 +/- 10%	Ohm
Voltage Vcc	3.3	V
LED forward voltage	1.5	V

<sup>1</sup> Mainly due to residual temperature effects

<sup>2</sup> Characterization done by Inspire AG and IWF/ETH Zurich

<sup>3</sup> See laser processing application note for details

## Housing

The EL-10-42-OF comes with a black metallic housing. The rectangular shaped part of the housing at the side includes the electrical connections. Four M3 thread holes located at the front surface of the housing are designated for mounting. A typical assembly is shown in section *Alignment and mounting*. The  $\varnothing 40.0$  mm and  $\varnothing 25.5$  mm diameter flank is tightly tolerated (ISO tolerance g6) and suitable as an alignment feature. The included Teflon washer provides thermal isolation and has to be placed between the EL-10-42-OF and an external holder.

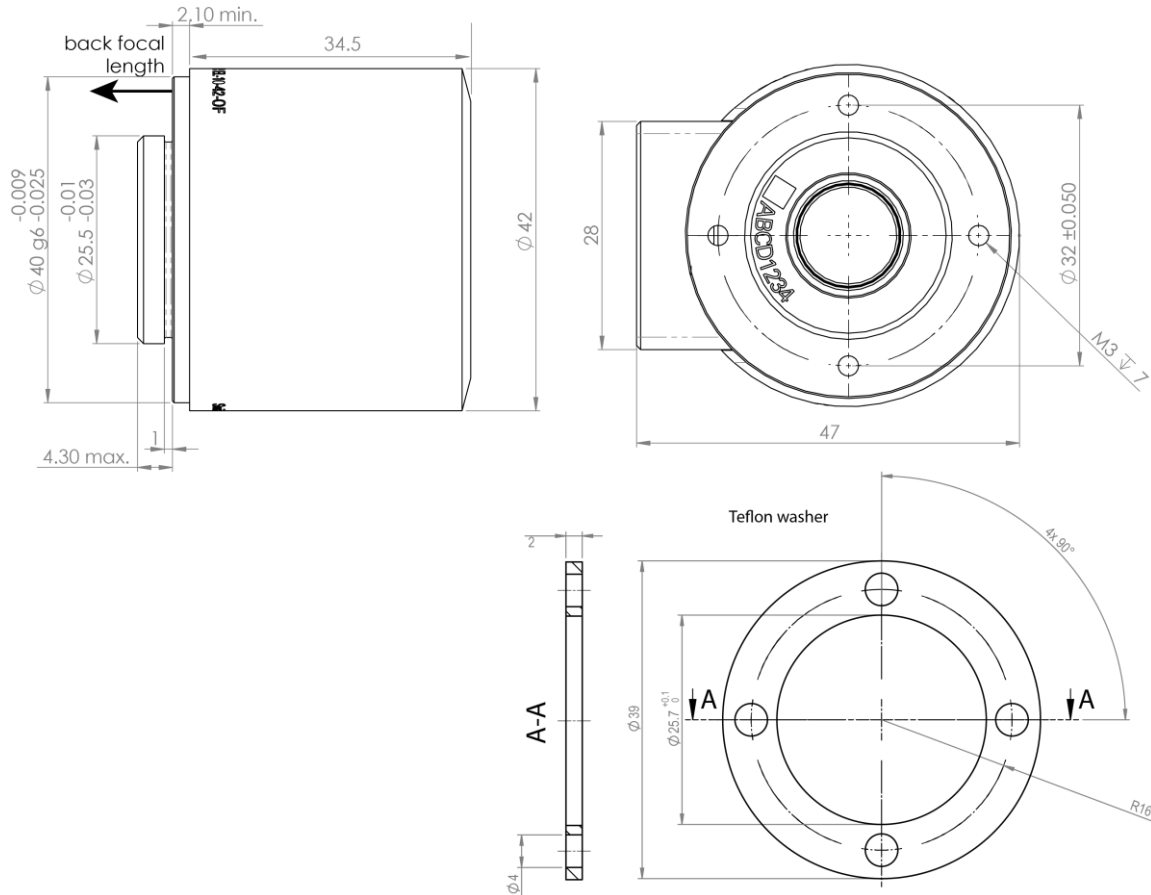


Figure 1: Mechanical drawing of the EL-10-42-OF (unit: mm). Four M3 thread holes are available for mounting. The Teflon washer has a thickness of 2mm and its flatness is tolerated within  $\pm 0.05$  mm.

## Electrical connection

The electrical connection of the EL-10-42-OF consists of two female 1.5 mm AMP Mini CT connectors with 6 and 8 pins (see e.g. [www.te.com](http://www.te.com), No. 292207-6 and 292207-8). The detailed pin-out is summarized in the table below.

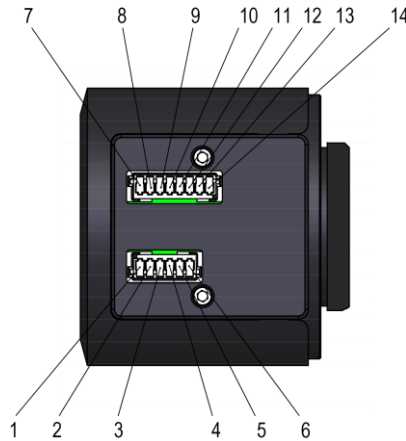


Figure 2: Electrical connections of EL-10-42-OF. Both connectors are of type 1.5 mm AMP Mini CT.

Pinning					
Position	Function	Value	Position	Function	Value
1	GND	-	8	Control current -	-
2	Heater in	Max. 12W	9	GND	-
3	Heater out	-	10	LED + Anode	30 mA @ 1.5V
4	I <sup>2</sup> C SDA	Digital signal	11	LED – Cathode	-
5	I <sup>2</sup> C SCL	Digital signal	12	Photodiode Common Cathode GND	-
6	Vcc	3.3V	13	Photodiode Anode back	Typ. 100 $\mu$ A
7	Control current +	0..350 mA	14	Photodiode Anode front	Typ. 100 $\mu$ A

## Optical power (focal length) versus current

The optical power of the EL-10-42-OF increases with increased current, shown in Figure 3. The working principle is based on Optotune's well-established technology of electrically tunable lenses. The core that forms the lens contains an optical fluid, which is sealed off with an elastic polymer membrane. An electromagnetic actuator is used to exert pressure on the container and therefore changes the curvature of the membrane such that the focal length is adjusted. By applying the electrical current to the coil of the actuator, the optical power of the lens is controlled.

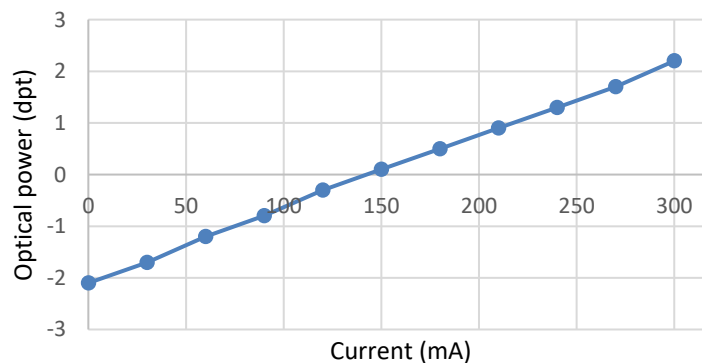


Figure 3: Typical data shows the linear relation between optical power (in diopters) and electrical current.

## Optical feedback signal

Optical feedback is used to stabilize the focus of the lens in real time. The way to establish optical feedback is to detect light passing through the lens, emitted from a built-in LED. There are two photodiodes installed inside the lens which are used to measure the LED light. The typical photodiode signals are as shown in Figure 4. The slopes of the two curves are different, and both photo currents strongly depend on the optical power of the lens. With subsequent electronics these currents are converted into voltages through transimpedance amplifiers. The normalized signal  $(V1-V2)/(V1+V2)$  of the two voltages V1 and V2 is then calculated in order to perform the optical feedback control for the lens. Note that the normalized signal is independent of intensity fluctuations of the LED.

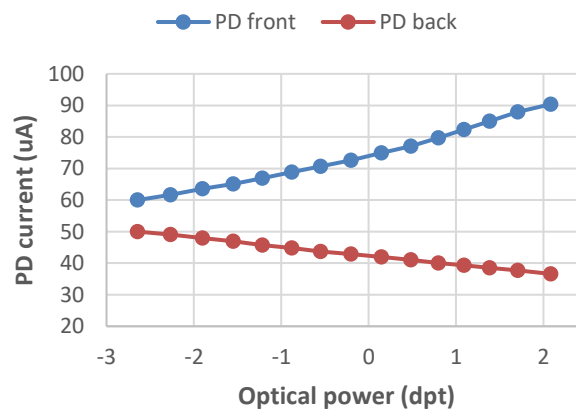
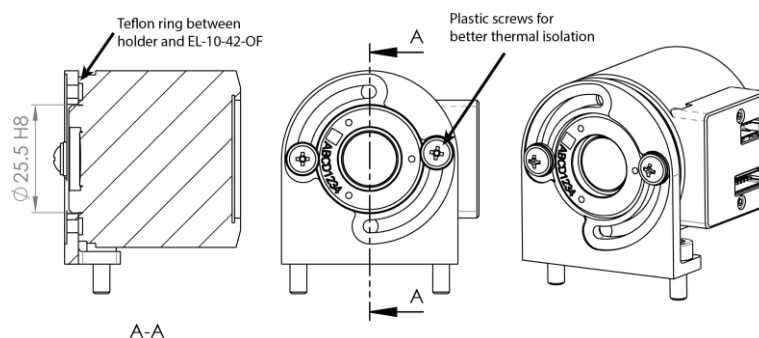


Figure 4: Output current from two photodiodes versus optical power of the lens.

## Alignment and mounting

An important aspect when mounting the EL-10-42-OF is to ensure proper alignment with respect to the optical axis. The figure below shows an implementation of a holder plate. For detailed dimensions in your design, we can provide a CAD file of the holder. We propose a scheme that utilizes the part of the smaller diameter of the lens which is specified with low tolerance (ISO g6). The through hole of the holder plate has the corresponding DIN tolerance H8. The lens is screwed from the front onto the holder plate. This guarantees best alignment with respect to the optical axis. The elongated holes give the rotational freedom to align the connectors, since the relative position of the connectors and the screw holes vary from lens to lens. For best thermal isolation, a Teflon washer (included in the package) has to be placed between the lens and the holder. Also, it is recommended to use plastic screws to fix the lens. In the case shown, the lens is rotated such that the connectors point to the side.



## Bode diagram

In order to characterize the dynamics of the EL-10-42-OF itself, which behaves similar to a mass-spring system, it is common to measure the Bode diagram. It contains both the magnitude of the frequency response and the phase shift. The result is shown in Figure 5 which is applicable as a generic model for the EL-10-42-OF. Lens to lens variations are negligible. The first resonance peak is at 200 Hz and in the same region the phase shift reaches  $-90^\circ$  and continues to lower values. The diagram gives an indication of the physical limit of the lens' maximum control speed, which will be around 100 Hz (half of the resonance frequency).

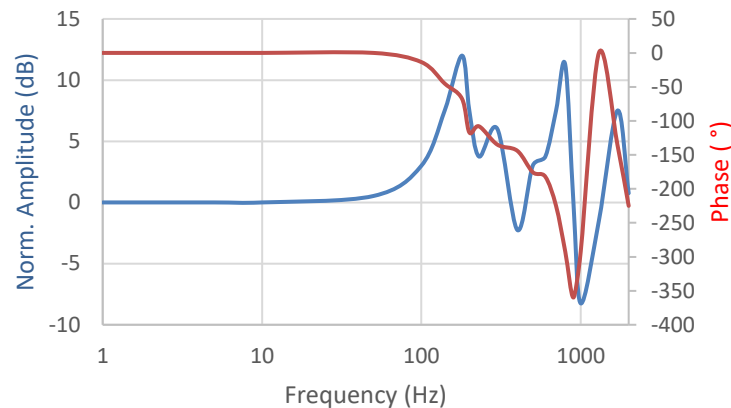


Figure 5: Bode diagram of the EL-10-42-OF. The amplitude is normalized to the DC limit (constant current) and shows a resonance at 200 Hz (blue curve). The phase shift is shown in red.

## Temperature stabilization

In order to have the highest focus stability, EL-10-42-OF lens is operated at a fixed temperature of  $47^\circ\text{C}$ . This can be achieved using the controller boards we provide. The set temperature is controlled using a PI controller for the heater element. When the lens is initialized, it requires a certain amount of time until the set temperature is reached. In Figure 6, two extreme conditions (environmental temperature of  $10^\circ\text{C}$  and  $40^\circ\text{C}$ ) are demonstrated. It can be seen that the system takes approximately 4 and 6 minutes respectively to get the temperature stable. After a short time, indicated by the red and blue arrows, the lens is set to maximum current (300 mA) in order to see the effect of additional heat input. Even for the  $40^\circ\text{C}$  environmental temperature only a small increase of about  $2^\circ\text{C}$  is visible, which is the desirable result.

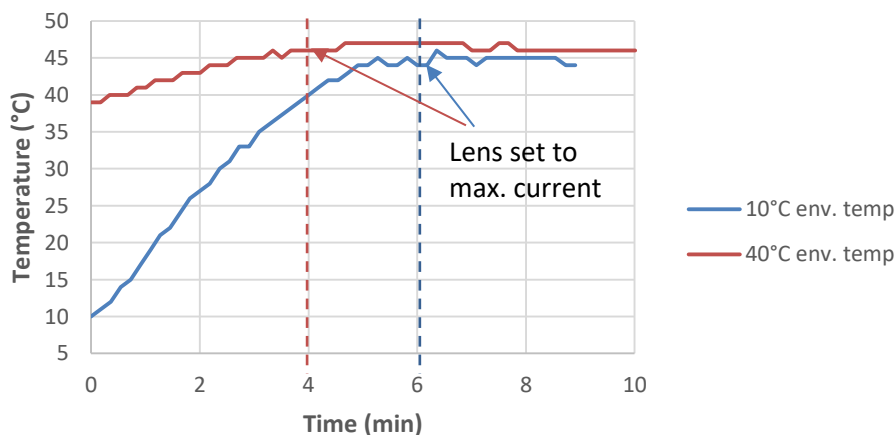


Figure 6: Initial heating phase for two extreme environmental temperatures  $10^\circ\text{C}$  and  $40^\circ\text{C}$ . It takes approximately 4 and 6 minutes (dashed vertical lines) until the set temperature is reached.

## Safety and compliance

The product fulfills the RoHS and REACH compliance standards. The customer is solely responsible to comply with all relevant safety regulations for integration and operation.

For more information on optical, mechanical and electrical parameters, please contact [sales@optotune.com](mailto:sales@optotune.com).