Fast Electrically Tunable Lens EL-3-10

The compact EL-3-10 lens was designed for OEM integration into optical systems for various applications. The working principle is based on the well-established shape-changing lens technology. The curvature of the lens is adjusted by applying an electrical current. Thereby, the focal length is tuned to a desired value within very few milliseconds. The lens architecture is “push pull” which means that the lens curvature is deflected from concave to convex. With actuators based on proven voice-coil technology, the EL-3-10 focus tunable lens is extremely reliable and robust, well suited even for applications in harsh environments over large temperature ranges.

Lens specifications

Clear aperture	3	mm
Focal power range (@20°C)[1]	-13 to +13	dpt
Transmission range	VIS: 420 to 900 NIR: 850 to 1600	nm
Wavefront error @ 0 mA (vertical/horizontal)	<0.2 / <0.2	λ RMS @532 nm (tighter spec available upon request e.g. 0.07 λ RMS)
Lens type	Plano-concave to plano-convex	
Refractive index / Abbe number	n_D = 1.300 / ν = 100	
Response time (80% step)	<1	ms
Settling time (80% step)	2 / 4	Ms (low pass filtered / normal step signal)
Lifecycles (10-90% sinusoidal)	>1’000’000’000	cycles
Optical damage threshold	>1	kW/cm²
Operating temperature	-20 to 65	°C
Storage temperature	-50 to 85	°C
Weight	1.25	g

Electrical specifications

Nominal control current	-120 to +120	mA
Operating voltage	-1…1	V
Coil resistance at 30°C	7.1	Ohm
Power consumption (full tuning range)	0 to 100	mW
Power consumption (+/- 5 dpt tuning range)	0 to 15	mW

Overview of available standard products

Standard Product	Tuning range	Flex cable	Cover glass	Container- and/or cover glass coating
EL-3-10-VIS-26D-FPC	-13 to +13 dpt	Yes	Yes	420 – 900 nm
EL-3-10-NIR-26D-FPC	-13 to +13 dpt	Yes	Yes	850 – 1600 nm
EL-3-10-VIS-26D-OEM	-13 to +13 dpt	No	No	420 – 900 nm
EL-3-10-NIR-26D-OEM	-13 to +13 dpt	No	No	850 – 1600 nm
EL-3-10-VIS-26D-OEM-CG	-13 to +13 dpt	No	Yes	420 – 900 nm

[1] Optical power ranges of up to +/-35 dpt are available on request

Mechanical drawings

The standard EL-3-10 lens has a flex cable (Figure 2), compatible with our EL-E-4 lens driver, designed for proto-typing and low volume applications. In addition, an OEM version of the EL-3-10 lens for high volume applications is available. It has two soldering pads that can be used to solder cables to or to connect with spring contacts (Figure 4). The full field of view towards the top is 50°. The full field of view towards the bottom is specified with 46°. For the OEM version, the protective cover glass is optional, allowing to optimize transmission.

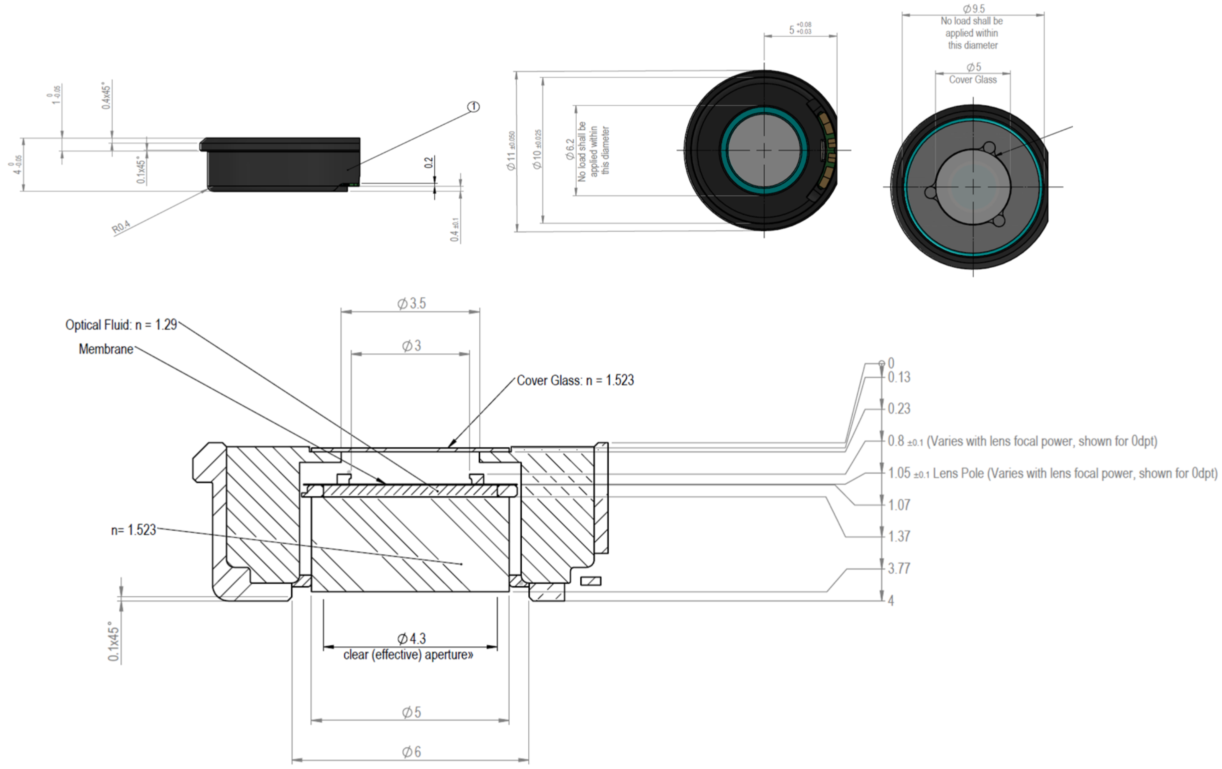


Figure 1: Mechanical drawing of the EL-3-10-XXX-26D-OEM lens

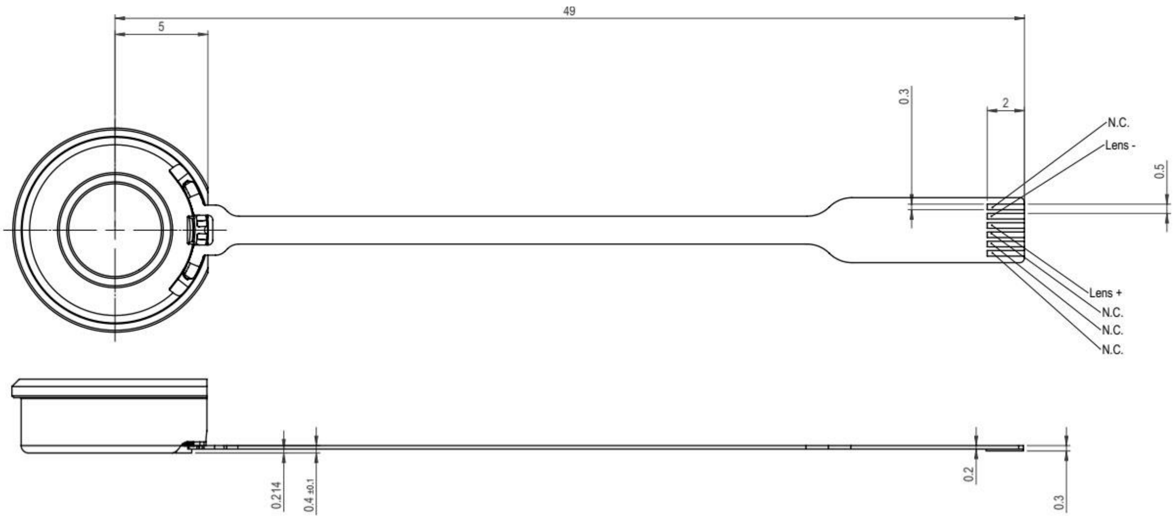


Figure 2: Mechanical drawing of the EL-3-10-XXX-26D-FPC lens

Mounting

To mount the lens, it is clamped on the flange. The orientation is defined by the D-cut. For version with no cover glass, on the bottom aperture, the membrane is exposed to the environment. Therefore, the lens needs to be integrated in a clean environment (e.g. clean room) and designed into an optical system so that the bottom interface is protected against dust.

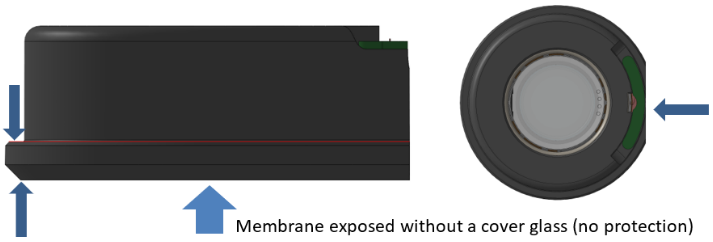


Figure 3: EL-3-10 mounting

Electrical connection

For the OEM version, on the two PCB solder pads, wires can be connected. Alternatively, spring loaded pins can be used for the contact on the PCB solder pads (for example TE 1551631-5).

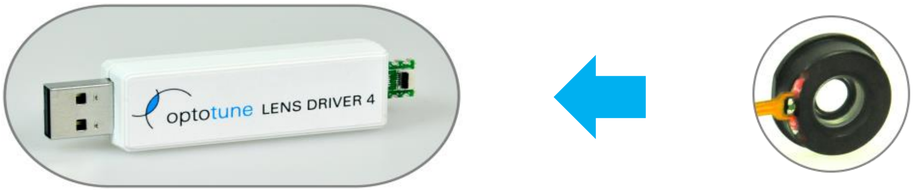
Figure 4: Soldering pads with spring loaded pins for EL-3-10-XXX-26D-OEM

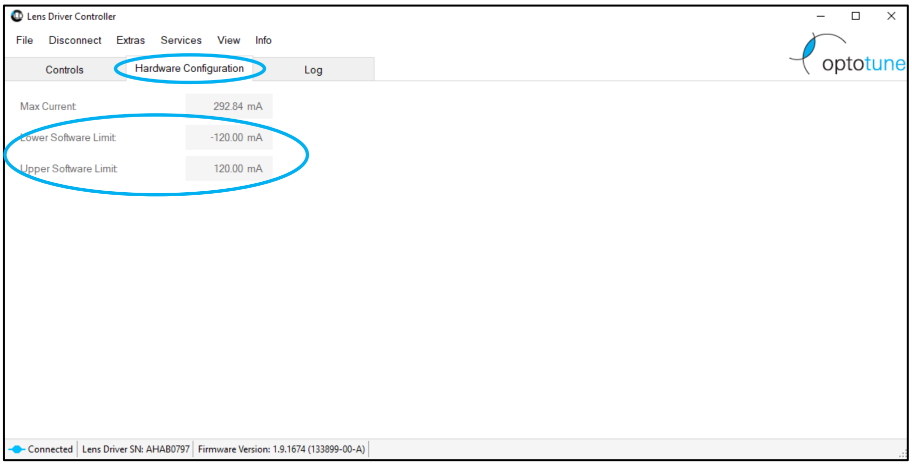
The standard FPC version has a flex cable soldered to the soldering pads descripted above and compatible with Optotune's lens driver 4, as shown in Figure 5.

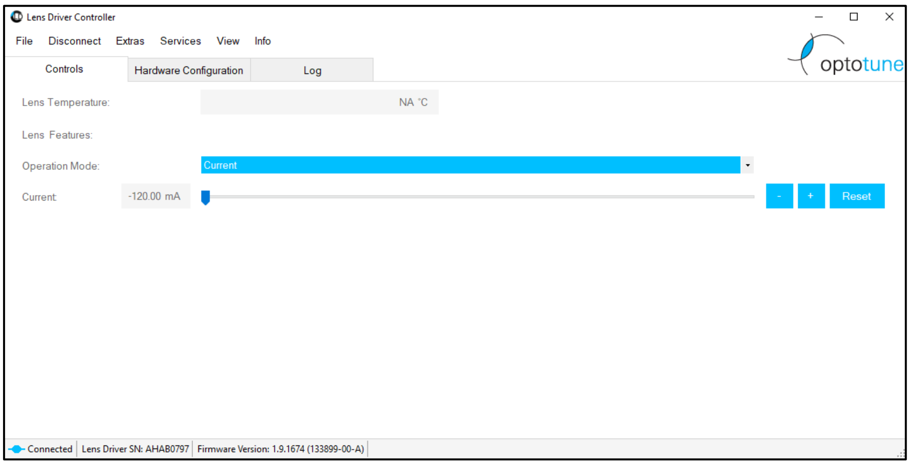
Figure 5: EL-3-10-XXX-26D-FPC with flex cable

Driver

The compact EL-3-10 lens can be driven with Optotune's EL-E-4 lens driver by simply connecting the flex cable of the lens to the Molex connector on the lens driver. In Optotune's software interface, the current to the lens can be adjusted to drive the lens. It's important to note that +/-120 mA are required to tune across the whole optical power range. As the lens driver can output more current, it must be connected to the PC without the lens connected first. Then, in the "Hardware Configurations" tab, the software limit must be set to +/-120mA. Afterwards the lens driver can be disconnected, the lens connected to the lens driver and the lens driver connected back to the PC. The current will now only be adjustable from +/-120mA, hence an overdriving of the lens can be prevented.







Instructions

1. Connect lens driver to the PC without a lens connected
2. Open the lens driver controller software
3. Go to the hardware configurations tab
4. Set the lower software limit to -120mA
5. Set the upper software limit to 120mA
6. Close the software window
7. Disconnect the lens driver
8. Connect the lens to the lens driver
9. Connect the lens driver to the PC
10. Open the lens driver controller software
11. Use the slider to adjust the current to the lens

Working principle

The working principle of the EL-3-10 is based on Optotune's well-established technology of shape-changing polymer lenses. The core that forms the lens contains an optical fluid, which is sealed off with an elastic polymer membrane as shown in Figure 6. An electromagnetic actuator is used to exert pressure on the container and therefore changes the curvature of the lens. By changing the electrical current flowing through the coil of the actuator, the optical power of the lens is controlled.

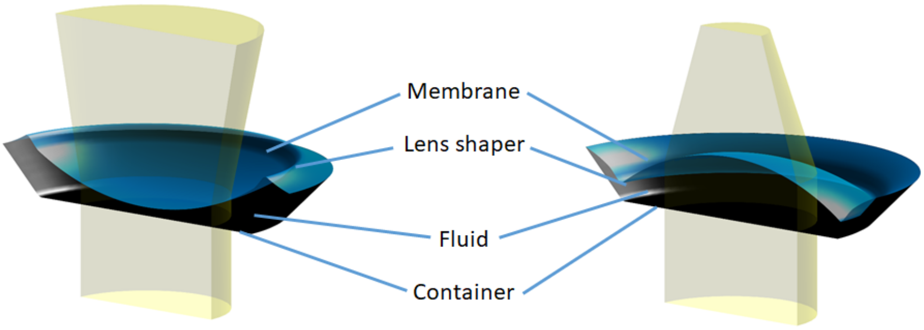


Figure 6: Scheme of the sealed lens container filled with an optical fluid and embedded in an EL-3-10 housing

Optical power versus current

The optical power of the EL-3-10 increases with positive current and decreases with negative current as shown in Figure 7. The specified optical power range is from +13 to -13 diopters.

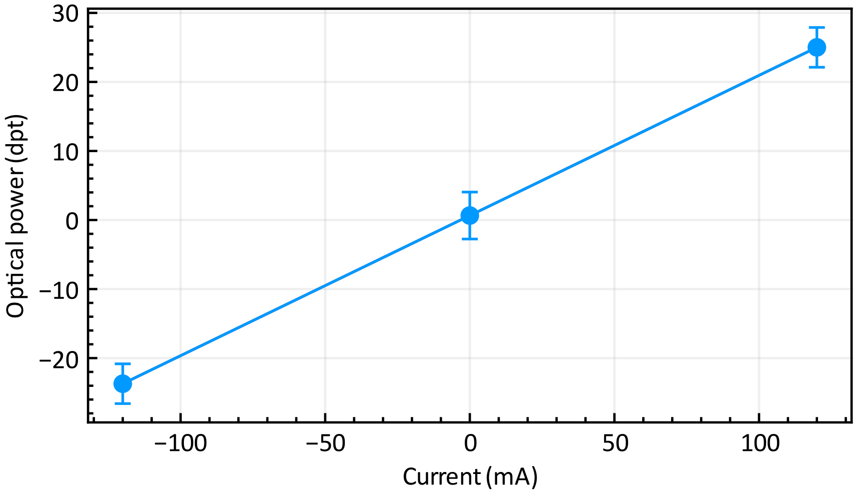


Figure 7: EL-3-10 typical current vs optical power graph

Transmission range

Both the optical fluid and the membrane material are highly transparent in the range of 400 to 2500 nm. As the membrane is elastic it cannot be coated using standard processes, hence a reflection of 3 – 4% is to be expected. Cover glasses can be coated as desired. Figure 8 shows the transmission spectrum for the standard VIS and NIR broad-band coating.

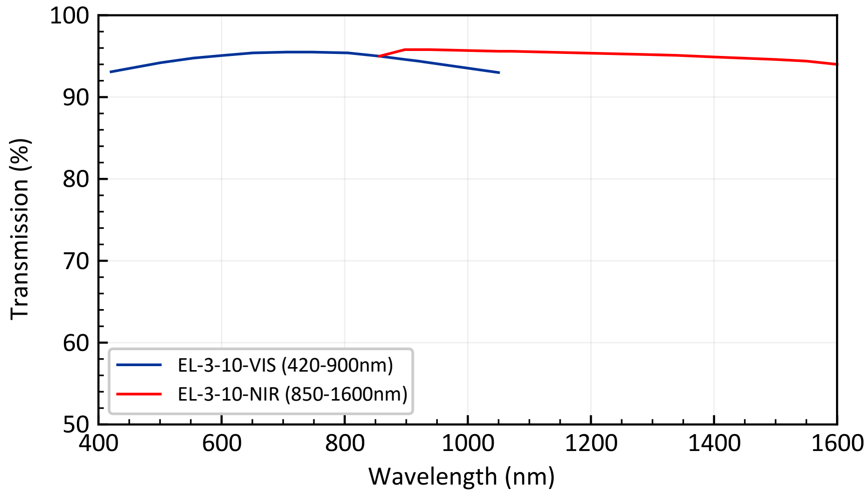


Figure 8: Transmission spectra of EL-3-10 standard VIS and NIR coating

Wavefront quality

In principle, Optotune's focus tunable lenses exhibit a spherical lens shape (the nominal parameters can be found in the ZEMAX package, which is available for download on).

Optotune's focus tunable lenses are typically subject to gravity induced coma aberrations when used in the horizontal optical axis. Due to the small clear aperture and stiff membrane of the EL-3-10 lens, there is no measurable Y-coma in the horizontal optical axis. However, the focal power of the EL-3-10 lens is slightly affected by acceleration. 1g results in about 0.15 dpt change in focal power. A typical wave front error across the whole focal power range can be seen in Figure 9 below.

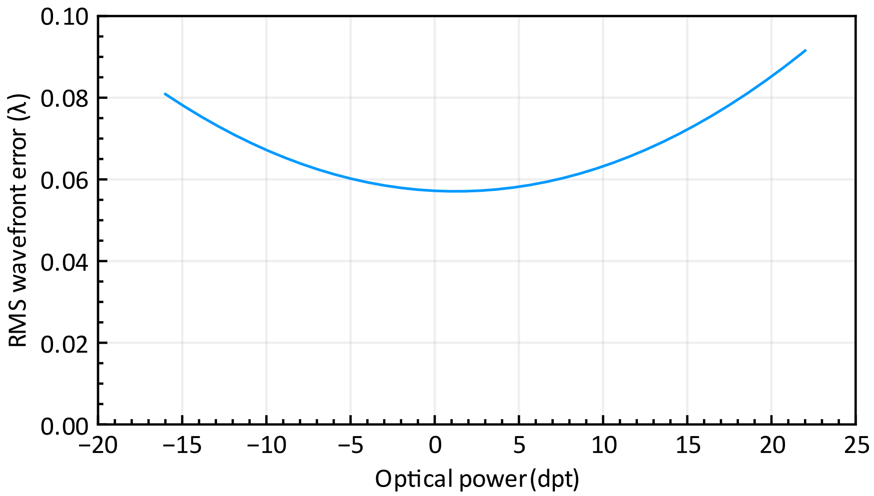


Figure 9: Typical RMS wave front error of the EL-3-10

Response time

The rise time when applying a current step is <1 ms and it takes only about 4 ms until the lens has fully settled. The graphs of the step response measurements below show the optical response of the EL-3-10 lens. Low pass filtering of the drive signal to the lens allows to damp the oscillations seen in the step response graphs below and as a result drive a controlled 80% step in <2ms.

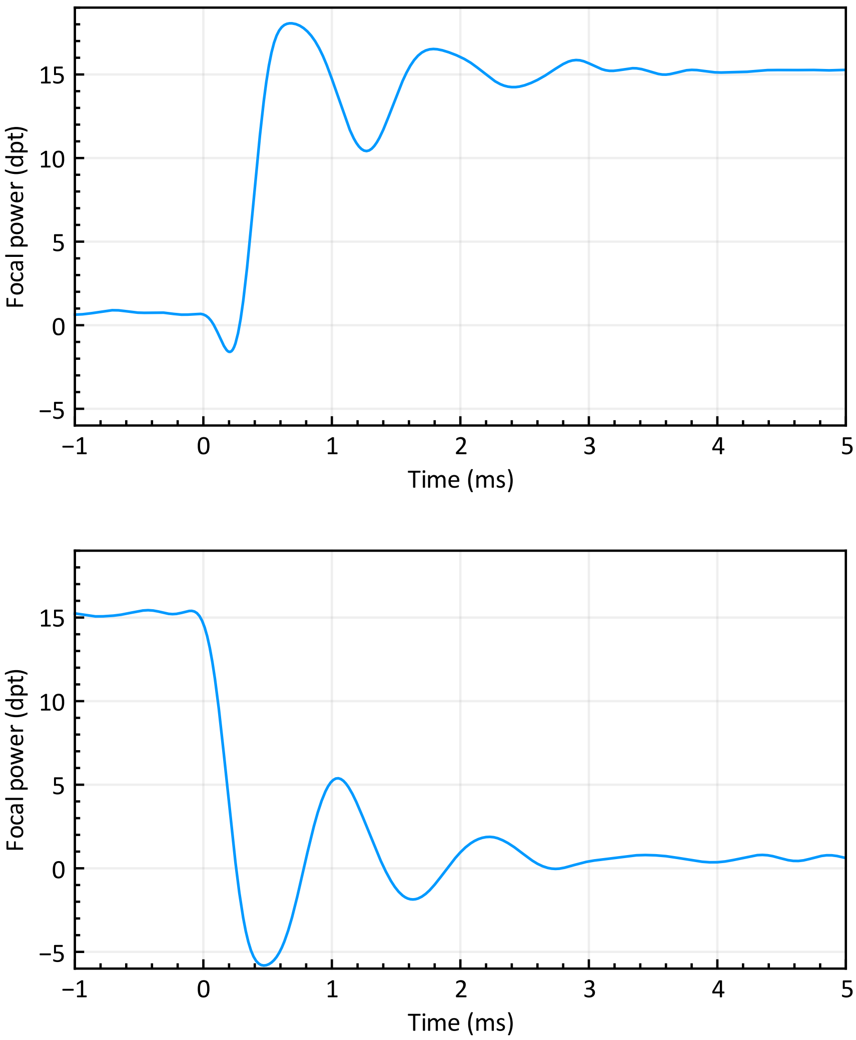


Figure 10: 80% step response of the EL-3-10 lens

The frequency response over a broad range is presented in Figure 11Figure 11, showing a resonance peak at around 475 Hz. Note that additional spherical aberrations are to be expected at or close to that resonant frequency, which might limit the use of the lens for certain applications at high frequencies.

When applying a current step, it is recommended to damp frequencies above 250 Hz range by using a low pass filter to avoid excitation oscillations as seen in Figure 10.

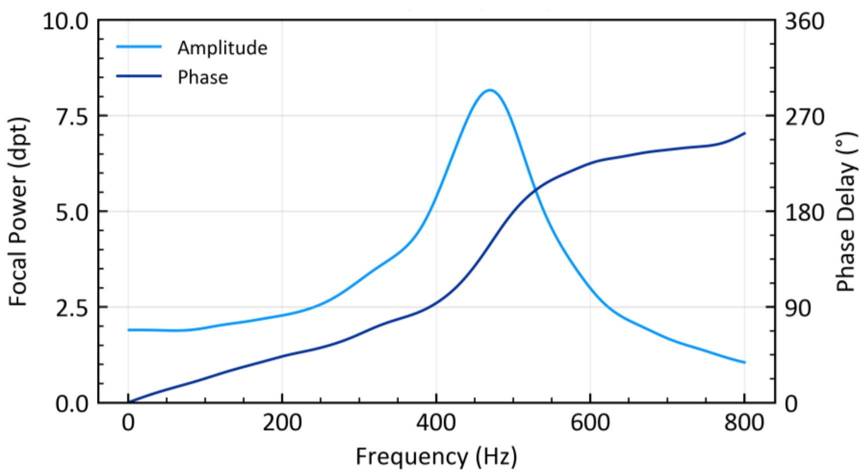


Figure 11: Typical frequency response and phase delay of the EL-3-10. The driving amplitude is -10 to 10 mA

Temperature effects

Residual temperature effects influence the long-term drift of the optical power. These temperature effects are quantified by the temperature sensitivity, giving the change in optical power per degree Celsius. Depending on the optical power, the sensitivity of the EL-3-10 increases or decreases according to the graph in Figure 12. For repeatable optical power driving across the whole temperature and optical power range, additional active temperature compensation is necessary. As the sensitivity decreases with increasing optical power, it is recommended to operate the EL-3-10 in the positive optical power range, where the sensitivity is lowest.

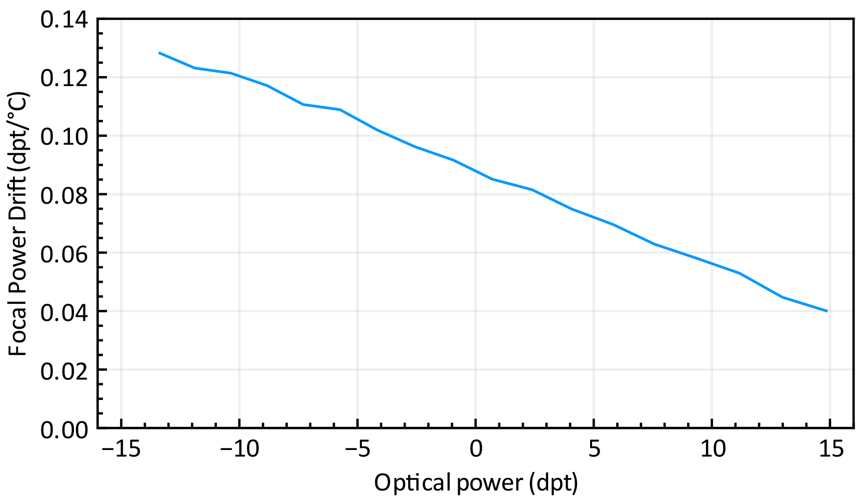


Figure 12: EL-3-10 temperature sensitivity across the optical power range

Optical layout

Zemax simulations to model the EL-3-10 lens within an optical design are available upon request.