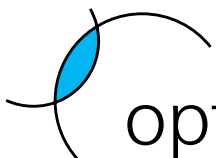




shaping the future of optics



optotune

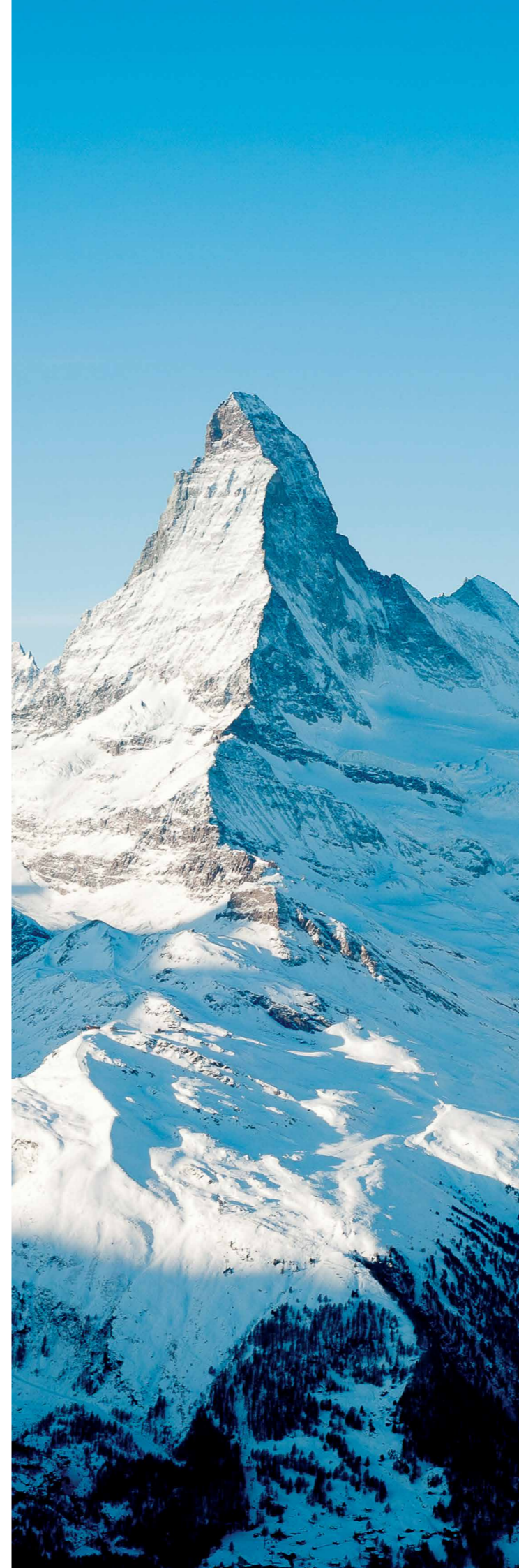
Focus **tunable** lenses

Enabling optical innovations

As a pioneer in adaptive optics, Optotune offers a range of tunable optical components that help you develop products with novel key features. Our experts support you in adding versatility, compactness and fast response to your optical systems.



Tell us about your application. We are happy to support your product development from concept to series.



Contents

Technology

- 4 Working principle
- 5 Response time
- 5 Wavefront quality
- 6 Transmission
- 6 Drivers and control modes

Products

- 7 Overview of tunable lenses
- 8 EL-3-10
- 10 EL-10-30
- 12 EL-10-42-OF
- 14 EL-16-40-TC
- 16 Overview of drivers
- 17 Lens Driver 4
- 17 EL-E-OF

Applications

- 19 Overview
- 20 Machine Vision
- 22 Laser processing
- 24 Ophthalmology
- 26 Microscopy

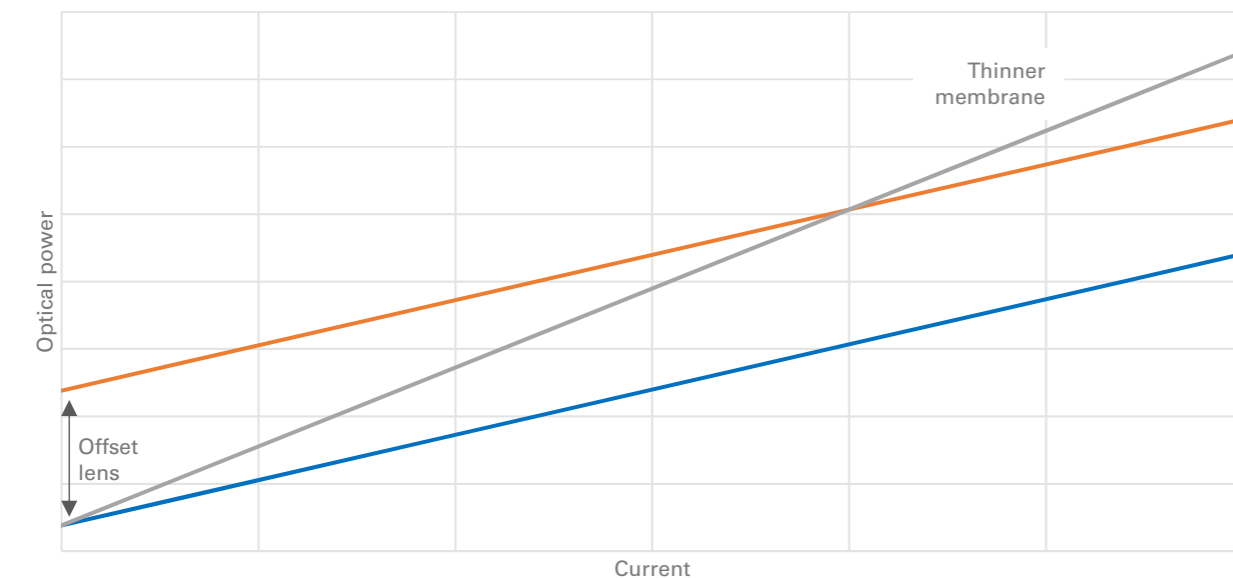
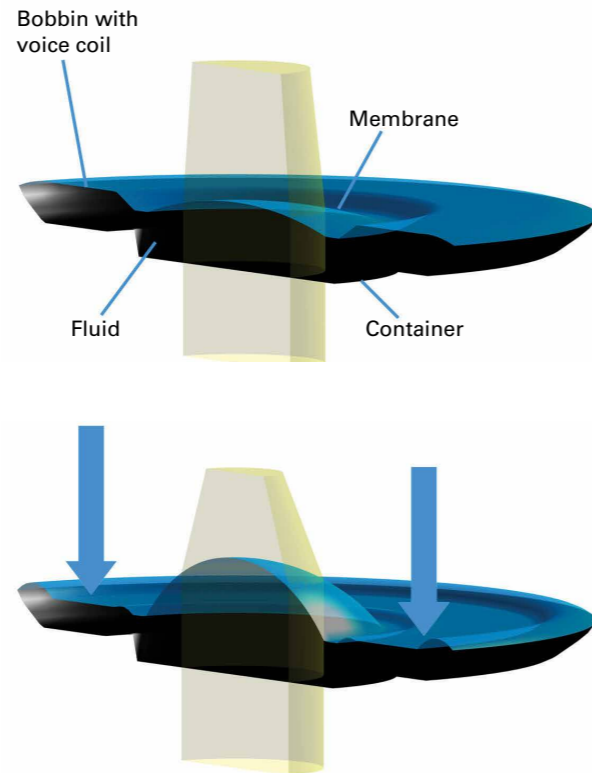
Technology

Working principle

Optotune's core technology is based on the principle of a shape-changing lens. It consists of a container, which is filled with an optical fluid and sealed off with an elastic polymer membrane. An electromagnetic actuator is used to exert pressure on the container, which leads to a deflection of the lens. As a result, the focal length of the lens is controlled by the current flowing through the coil of the actuator. In fact, the relation between current and optical power, which is the inverse of focal length, is linear.

Most tunable lenses are designed to deflect in positive direction, which means that the actuator pushes towards the membrane. To achieve negative optical powers a plano-concave offset lens is added. Newer generations of lenses have an actuator that is bonded to the membrane and is able to pull the membrane away from the container with negative currents, resulting in a concave lens shape. Hence negative optical powers are realized without an additional offset lens.

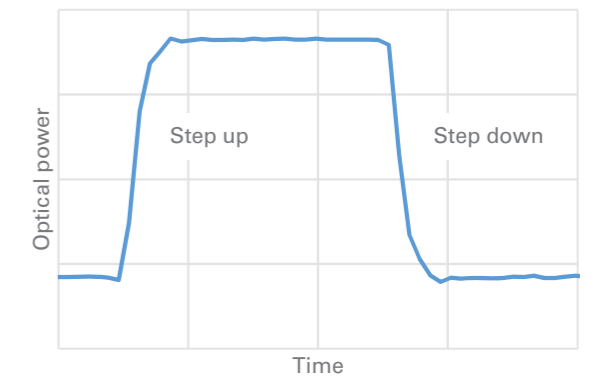
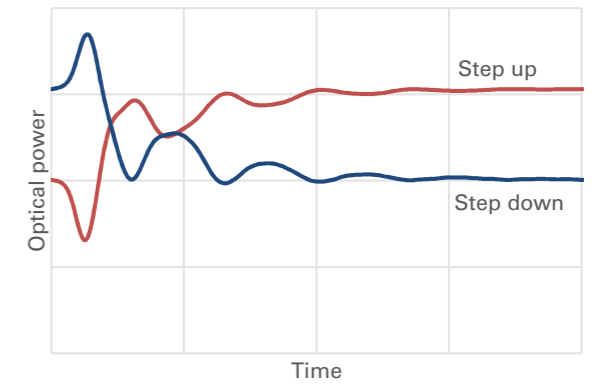
An important parameter to influence the tuning range of the lens is the membrane thickness. With thinner membranes, larger ranges of optical power are possible due to the reduced restoring force. Furthermore, the refractive power of the lens can be adapted by different optical fluids with different index of refraction. As a standard, Optotune uses a fluid with refractive index of about 1.3 with very low dispersion (Abbe number of 100), making it suitable for polychromatic applications.



Response time

Similar to a mass-spring system, the lens has a small but finite response time. This is mostly due to the inertia of the liquid, against which the actuator has to work. When applying a current step, the rise time of the lens is in the order of only a few milliseconds. Due to resonant excitations, it takes about 10 to 20 ms until the lens has fully settled, depending on the size of the lens. The figure on the right shows the optical response to a current step measured with a quadrant photo diode. The measurements were performed at room temperature.

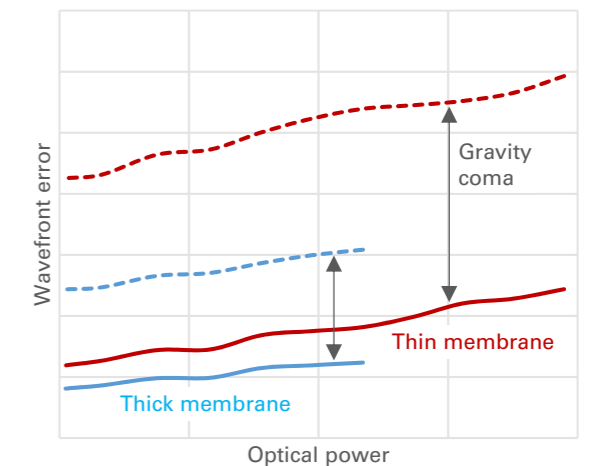
Resonances are significantly dampened when either an optimized current step or a close-loop system is used. The figure on the right shows such a step response using the EL-10-42-OF with an integrated optical feedback for closed loop optical power control. As a result, no oscillations appear.



Wavefront quality

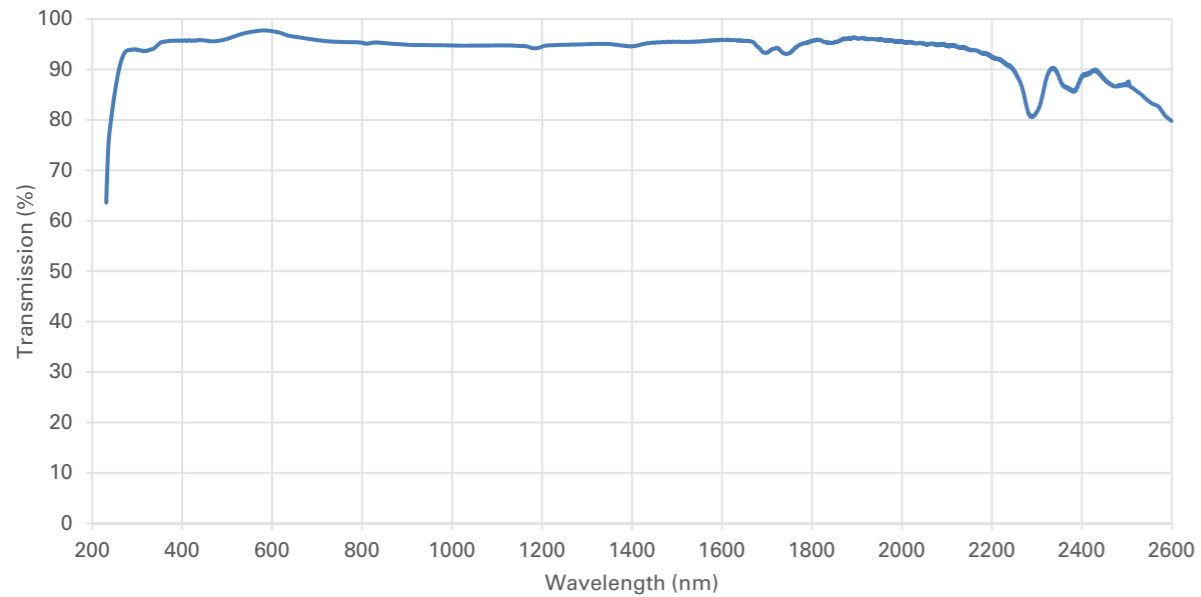
In principle, Optotune's focus tunable lenses exhibit a spherical lens shape. The RMS wavefront error is typically around 0.1 lambda (measured at 525 nm over an 8 mm clear aperture), allowing for high quality imaging and microscopy. In general thinner membranes allow for larger tuning ranges, however trend towards an increased wavefront error. This is shown by the blue and red solid line in the figure on the right.

As the membrane is elastic, the lens shape is influenced by gravity. With the lens standing upright (optical axis horizontal) a Y-coma term due to gravity must be added. This is illustrated by the dashed and solid red lines in the figure on the right. Thicker membranes are stiffer and hence are less sensitive to gravity effect as can be seen by the dashed and solid lines. For optimal performance it is therefore recommended to work with vertical optical axis.



Transmission

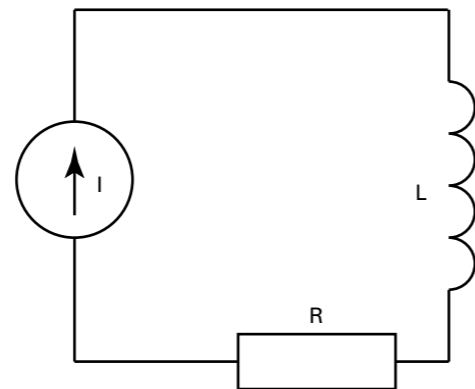
Both the optical fluid and the membrane material are highly transparent from 400 to 2500nm. The transmission spectrum below represents the transmission of the lens material only, i.e. assuming perfect cover glasses. As the membrane is elastic, it cannot be coated using standard processes, hence a reflection of about 4% results. For the cover glasses, Optotune offers two standard broad-band coatings in the visible and near-infrared range. If required, cover glasses can be coated for special wavelengths.



Drivers and control modes

The equivalent circuit that describes the general behavior of Optotune's electrically tunable lenses is an LR-circuit, as depicted on the right side.

In order to drive the electrically tunable lenses, standard current sources can be used. However Optotune offers suitable driving electronics. The Electrical Lens Driver 4 and 4i provide a simple way to drive most of Optotune's electrically tunable lenses. It is essentially a compact sized programmable current source offering serial communication via a virtual COM port (USB) or a UART interface. The driver can be used as a standalone solution or integrated into OEM designs.



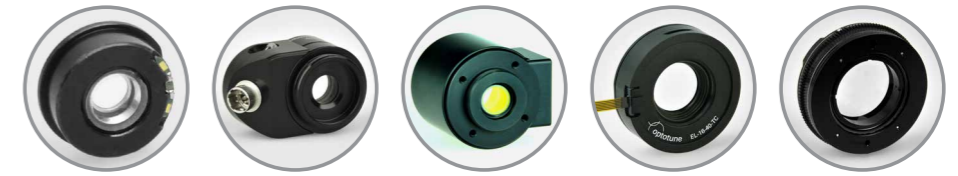
Different control modes such as "current mode" and "focal power mode" are available. The focal power mode keeps the optical power of the lens constant rather than the current by taking the temperature information and internal calibration data of the lens into account. As a result the focus drift due to temperature effects is significantly reduced.

For highest precision and focus stability, certain lenses offer closed-loop operation based on an optical feedback. The EL-E-OF electronics enables the control of lens modules containing an optical feedback, e.g. the EL-10-42-OF.

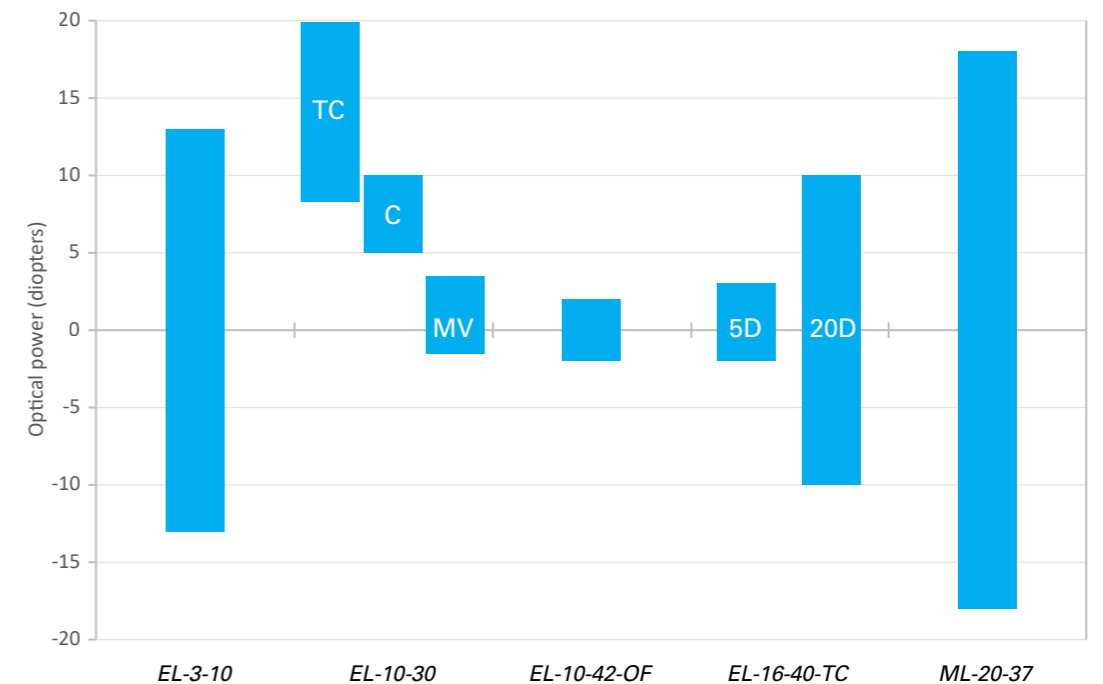
Products

Overview of tunable lenses

The following table outlines the main specifications of Optotune's standard tunable lenses.



	<i>EL-3-10</i>	<i>EL-10-30</i>	<i>EL-10-42-OF</i>	<i>EL-16-40-TC</i>	<i>ML-20-37</i>
Clear aperture	3mm	10mm	10mm	16mm	20mm
Optical power at nominal control current*	-13 to 13 dpt	-1.5 to 3.5 dpt 5 to 10 dpt	-2 to 2 dpt	-2 to 3 dpt -10 to 10 dpt	-18 to 18 dpt
Typical optical power reproducibility	Temperature dependant	+/- 0.1 dpt	+/- 0.01 dpt	+/- 0.1 dpt	Depends on motorization
Standard cover glass coatings	420 – 900 nm 850 – 1600 nm	400 – 700 nm 700 – 1100 nm	532 nm 950 – 1100 nm	420 – 1500 nm	400 – 700 nm
Nominal control current with Lens Driver 4	-120 to +120 mA	0 to 250 mA	0 to 350 mA	-250 to 250 mA	NA
Absolute maximum control current	-120 to +120 mA	0 to 400 mA	0 to 350 mA	-500 to 500 mA	Depends on motorization
Wavefront quality** over 8mm clear aperture	NA	<0.15 / <0.25λ	<0.1 / <0.2λ	<0.1 / <0.2λ	<0.25λ
Wavefront quality** over 80% clear aperture	<0.15 / <0.15λ	<0.15 / <0.25λ	<0.1 / <0.2λ	<0.25 / <0.5λ	NA
Response times***	1 / 2 / 4 ms	2.5 / 6 / 15 ms	- / 12 / - ms	5 / 12 / 25 ms	NA
Built in sensors	None	Temperature	Optical feedback	Temperature	None



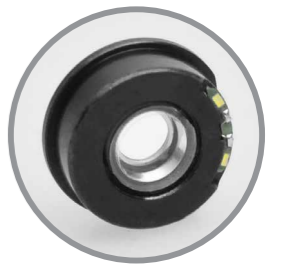
* Optical power range differs for configurations of different membrane thicknesses and offset lenses

** Wavefront error provided in λ RMS @525 nm with optical axis vertical / horizontal

*** 10-90% of step / settling time of a controlled step / settling time of rectangular step

Electrically tunable lens EL-3-10

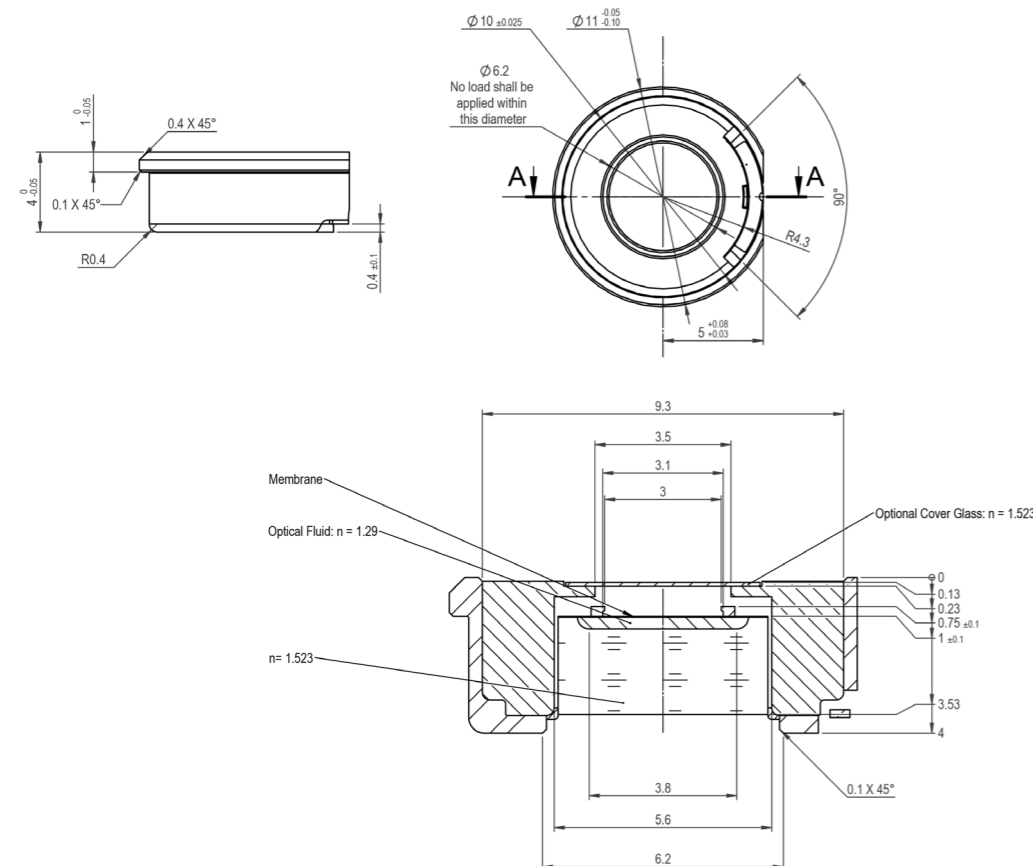
The OEM solution



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 a 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.

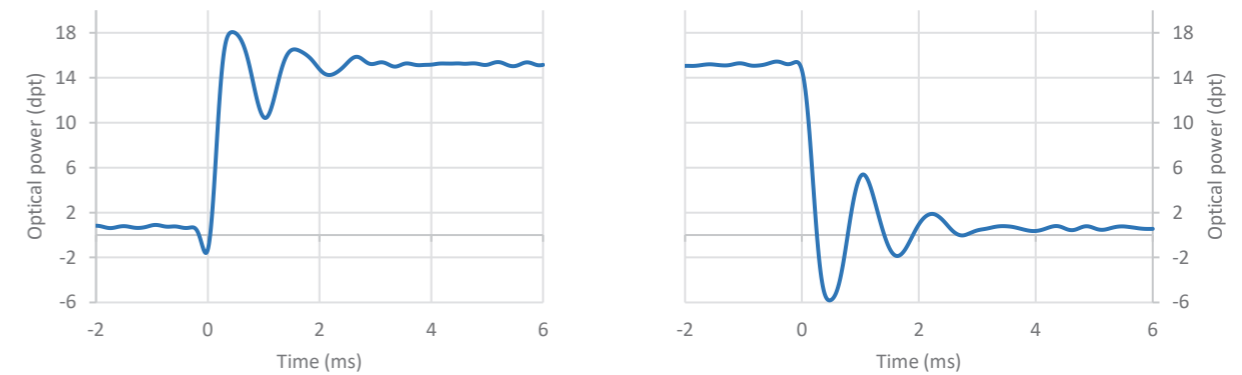
- Applications:
- > Microscopy
 - > Biometric systems
 - > Optical coherence tomography
 - > Laser illumination
 - > Laser shows

Specifications	
Dimensions (W or ϕ x thickness)	10x4 mm
Clear aperture	3 mm
Optical power	From -13 to +13 dpt (-77 to inf to +77 mm)
Transmission (>94%)	420 to 1600 nm (VIS and NIR coating options)
Response time (10-90% step), settling time of a controlled step, settling time of rectangular step	1 ms, 2 ms, 4 ms
Temperature control / optical feedback	No
Operating temperature	-20 to 65°C



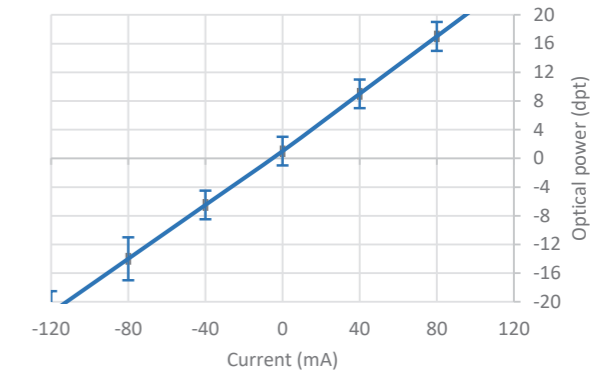
Fastest liquid lens on the market

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 14 diopter step in <2ms.



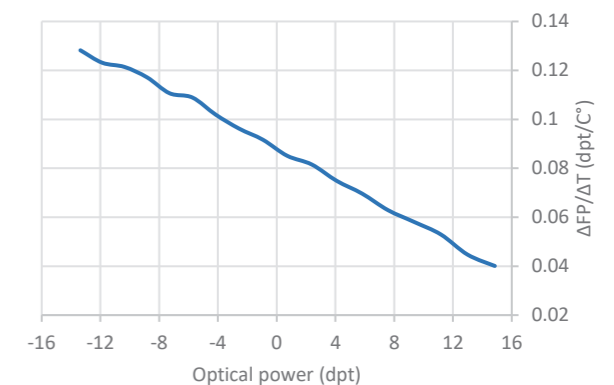
Optical power range

The optical power of the EL-3-10 increases with positive current and decreases with negative current as shown in the graph on the right. The achievable optical power range is from +13 to -13 diopters for a control current from +120 to -120 mA.



Temperature sensitivity

Residual temperature effects influence the long term drift of 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 temperature sensitivity of the EL-3-10 increases or decreases according to the illustration on the right. Additional active temperature compensation may be necessary when using the lens over the whole temperature and optical power range. As illustrated in the graph on the right, the temperature sensitivity decreases with increasing optical power. Hence, it is recommended to work in the positive optical power range, where temperature sensitivity is lowest.



Electrically tunable lens EL-10-30

The seasoned all-rounder

Launched in 2010, the EL-10-30 lens family covers a broad application range with its variety of coatings and housing options. The lens architecture is “push only” which means that the lens curvature is already slightly positive at zero current and increases further in positive direction by applying a positive current to the actuator. The C-mount version can accommodate a standard off-the-shelf offset lens inside the housing, allowing for customization of the optical power at zero current. Optotune’s “MV” models include a negative offset lens in order to access the negative focal length range. All EL-10-30 lenses are now equipped with an internal temperature sensor and EEPROM containing lens specific calibration data (diopter value vs current for different temperatures). This allows

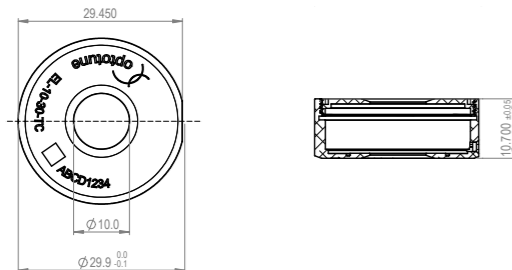
for good reproducibility in the so called “focal power mode”, where the user sets focal length instead of driving current. Two different connector versions are available. The OEM version suitable for integration into a housing and the industrial version for standalone applications feature a flex cable and a robust self-locking Hirose connector, respectively.

Applications:

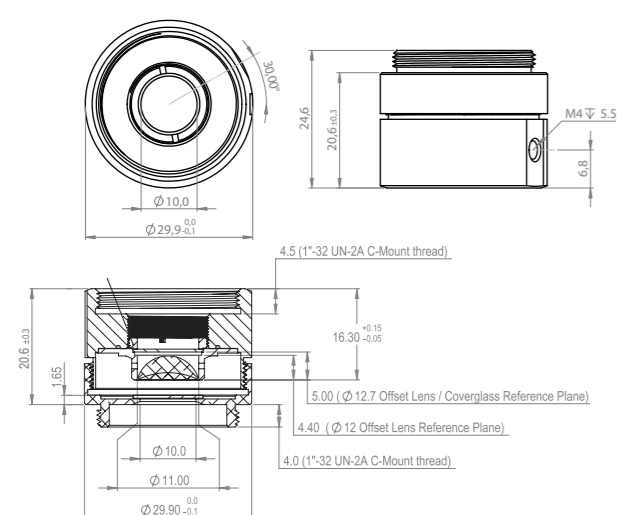
- > Machine vision
- > Microscopy
- > Biometric systems
- > Optical coherence tomography
- > Laser shows

Specifications	
Dimensions (W or ϕ x thickness)	30 x 10.7 mm (compact), 30 x 20.6 mm (C-mount)
Clear aperture	10 mm
Optical power (see configuration table)	From -1.5 up to +20 dpt (-666 to inf to +50 mm)
Transmission (>90%)	400 to 1100 nm (VIS and NIR coating options)
Response time (10-90% step), settling time	2.5 ms, 15 ms
Temperature control / optical feedback	TC
Operating temperature	-20 to 65 °C

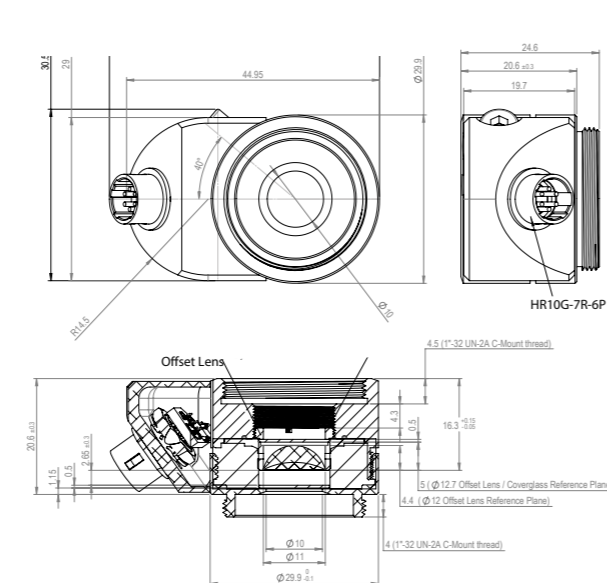
EL-10-30-TC (OEM version)



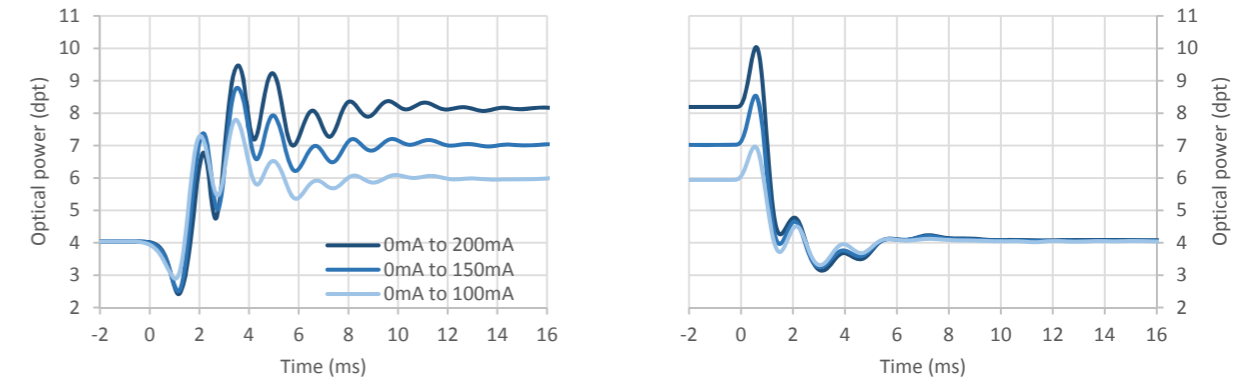
EL-10-30-C (OEM version)



EL-10-30-Ci (industrial version)

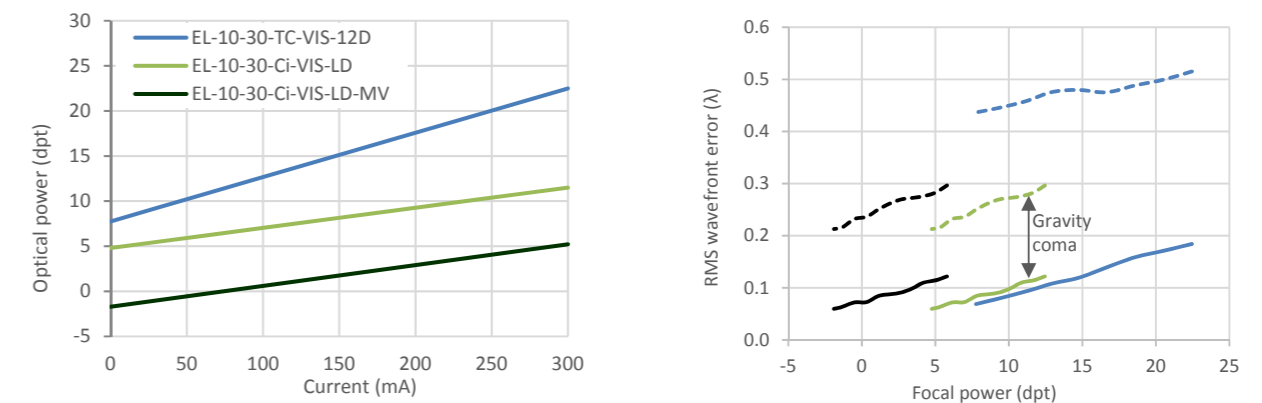


Response times in the millisecond range



Optical power range and wavefront quality depend on membrane thickness

An advantage of Optotune’s lens technology is that different membrane parameters can be used. The compact EL-10-30-TC series have a fairly thin membrane, which allows for a large optical power range of 12 diopters. The EL-10-30-C and -Ci series have a thicker membrane, which offers a smaller range of 5 diopters, but provide better wavefront quality when the optical axis is horizontal.



Standard Product	Tuning range	Offset lens	Temp. sensor	Cover glass coating	Wavefront error*
EL-10-30-TC-VIS-12D	+8 to +20 dpt	-	•	400 – 700 nm	<0.25 / <0.6λ
EL-10-30-TC-NIR-12D	+8 to +20 dpt	-	•	700 – 1100 nm	<0.25 / <0.6λ
EL-10-30-C-VIS-LD	+5 to +10 dpt	-	•	400 – 700 nm	<0.15 / <0.25λ
EL-10-30-C-NIR-LD	+5 to +10 dpt	-	•	700 – 1100 nm	<0.15 / <0.25λ
EL-10-30-C-VIS-LD-MV	-1.5 to +3.5 dpt	-150 mm	•	400 – 700 nm	<0.15 / <0.25λ
EL-10-30-C-NIR-LD-MV	-1.5 to +3.5 dpt	-150 mm	•	700 – 1100 nm	<0.15 / <0.25λ
EL-10-30-Ci-VIS-LD	+5 to +10 dpt	-	•	400 – 700 nm	<0.15 / <0.25λ
EL-10-30-Ci-NIR-LD	+5 to +10 dpt	-	•	700 – 1100 nm	<0.15 / <0.25λ
EL-10-30-Ci-VIS-LD-MV	-1.5 to +3.5 dpt	-150 mm	•	400 – 700 nm	<0.15 / <0.25λ

* Wavefront error provided in λ RMS @525nm with optical axis vertical / horizontal

Electrically tunable lens EL-10-42-OF

Optical feedback for highest reproducibility



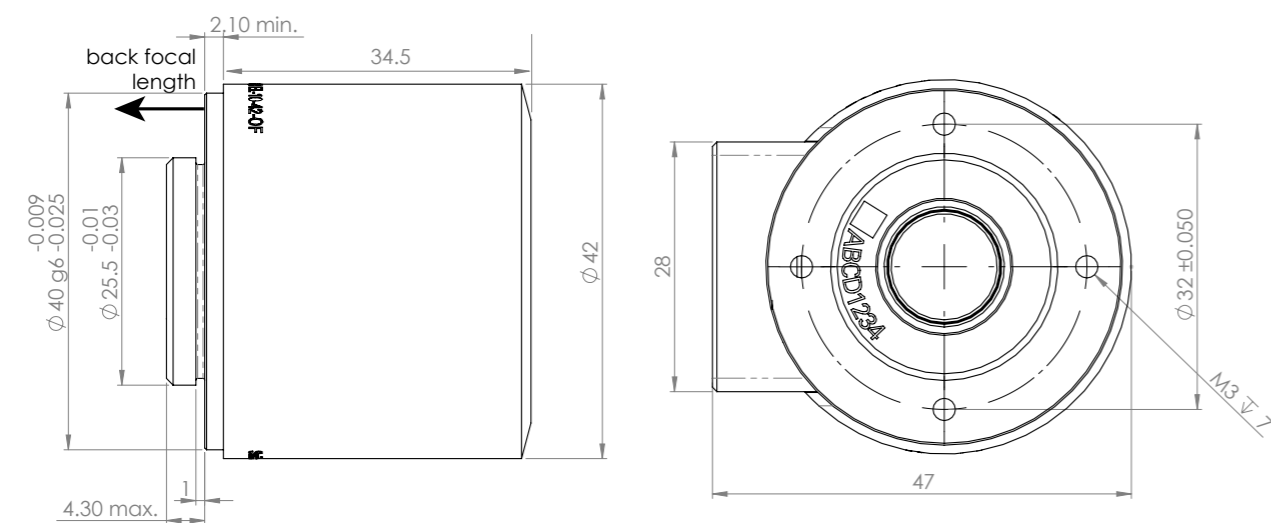
The EL-10-42-OF is Optotune's most precise lens thanks to integrated optical feedback. The working principle is based on the well-established shape-changing lens technology. The curvature of the lens is adjusted by applying an electrical current. Thereby, the focal length is tuned to a desired value within milliseconds. The integrated optical feedback measures the optical power of the lens in real-time, allowing for precise closed loop control. In addition, a temperature stabilization system allows the lens to operate within a narrow temperature range, further stabilizing the lens to provide highest reproducibility over a large ambient temperature range. Optimal control is guaranteed in combination with the EL-E-OF-A electronics.

its high optical quality, reproducibility and speed, Optotune's EL-10-42-OF is the perfect choice for laser processing applications.

Applications:

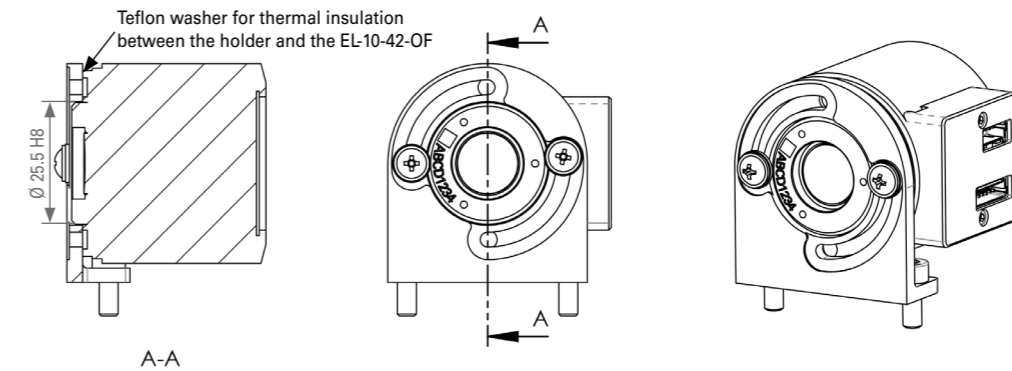
- > Laser marking
- > Laser cleaning
- > Laser micromachining
- > Laser microwelding
- > Laser direct structuring

Specifications	
Dimensions (W or ϕ x thickness)	42 x 47 mm
Clear aperture	10 mm
Optical power tuning range	-2 to +2 dpt (-500 to inf to +500 mm)
Optical power repeatability	<0.01 dpt
Transmission (>94%)	950 to 1100 nm
Damage threshold ³ @ 1064 nm:	
125 ns-pulsed at 50 kHz	2.60 J/cm ²
10 ps-pulsed at 50 kHz	2.05 J/cm ²
Damage threshold @ 532 nm:	
1 ns-pulsed at 300 kHz	0.19 J/cm ²
10 ps-pulsed at 50 kHz	0.11 J/cm ²
Wavefront quality over 80% clear aperture*	<0.1 / <0.2 λ
Response time (10-90% controlled step)	12 ms (analog driver), 8 ms (digital driver)
Stabilized operating temperature	47 °C
Temperature control / optical feedback	OF
Operating temperature	10 to 40 °C
* Wavefront error provided in λ RMS @525nm with optical axis vertical / horizontal	



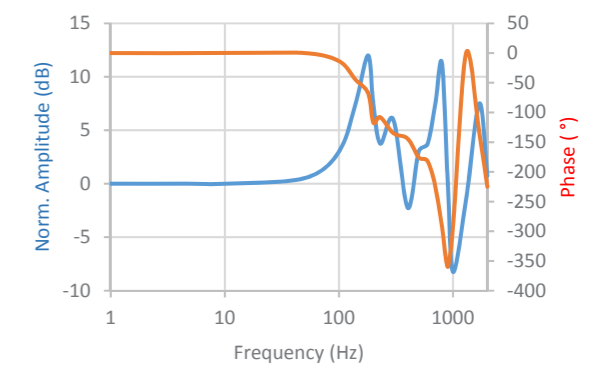
Alignment and mounting

An important aspect when mounting the EL-10-42-OF is to ensure proper alignment with respect to the optical axis. Using a holder plate as shown below is suggested. For detailed dimensioning in your design, please refer to the technical drawings of the lens' housing. We propose a scheme that utilizes the part of the outer diameter of the lens which is specified with low tolerance (ISO g6). The through hole of the holder plate has the corresponding ISO 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's front face and the holder. Also, it is recommended to use plastic screws to fix the lens. In the illustration below the lens is rotated such that the connectors point upwards.



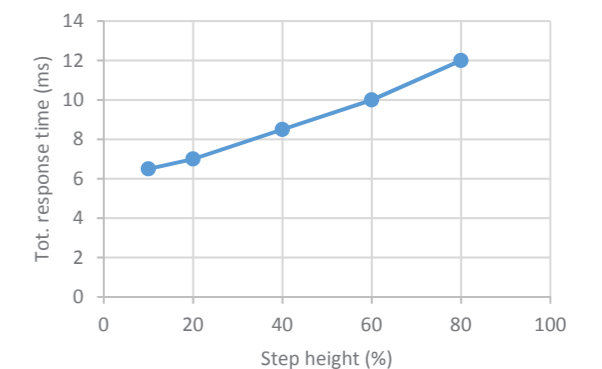
Bode diagram

The EL-10-42-OF shows a relatively broad resonance peak at 200 Hz and in the same region the characteristic sign change of the phase appears. The diagram gives an indication of the physical limit of the lens's maximum control speed, which is around 100 Hz (half of the resonance frequency).



Step response

The step response of the EL-10-42-OF driven by the EL-E-OF-A (analog driver) electronics board, for various step heights is shown.



Electrically tunable lens EL-16-40-TC

Large aperture and high reproducibility

With a clear aperture of 16 mm Optotune presents the world's largest electrically focus tunable lens. Its design has been optimized in many ways:

- > The 60% larger aperture than its predecessor allows for 2.5x more light throughput
- > Flat, zero optical power state
- > Strong actuator offers an optical power range of up to -10 to +10 diopters ("push/pull design")
- > Low thermal drift allows for high reproducibility
- > High pointing accuracy
- > Compact design

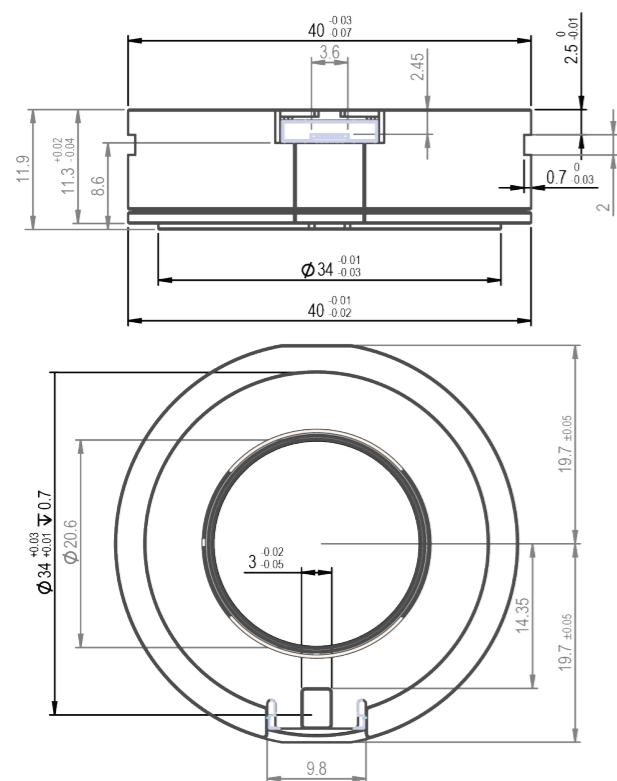
The EL-16-40-TC is available in its compact form for OEM integration but also with multiple thread adapters and a robust Hirose connector for industrial use, where the tunable lens can be easily combined with off-the-shelf imaging lenses.

Applications:

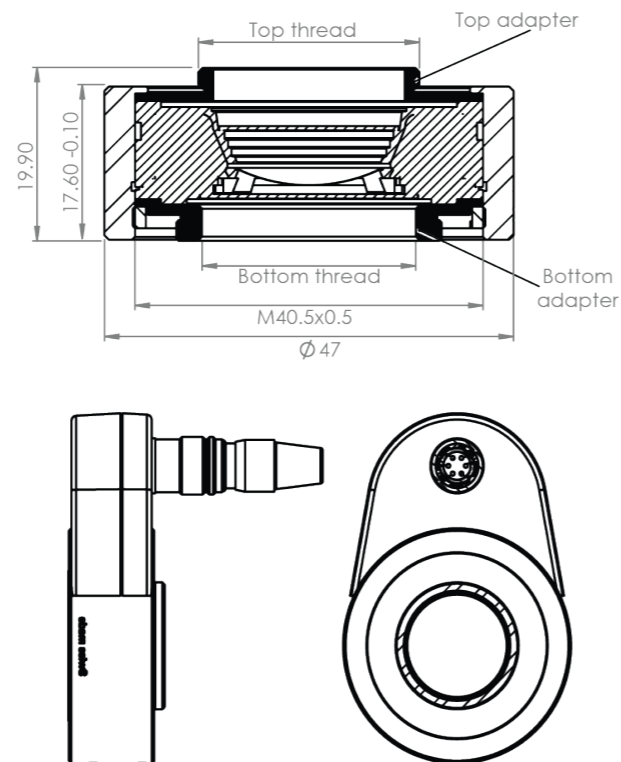
- > Machine vision
- > Microscopy
- > Phoropters
- > Augmented reality
- > Night vision

Specifications	
Dimensions (ø x thickness)	40 x 11.9 mm
Clear aperture	16 mm
Optical power with Optotune's Lens Driver 4 (-250 to +250 mA)	-2 to +3 dpt (-500 to inf to +333 mm) for 5D model -10 to +10 dpt (-100 to inf to +100 mm) for 20D model
Transmission range (>90%)	420 to 1500 nm (VIS and NIR coating options)
Response time (10-90% step), settling time	5 ms, 25 ms
Lifecycles (10%-90% sinusoidal)	>1'000'000'000
Temperature control / optical feedback	TC
Operating temperature	-20 to 65°C

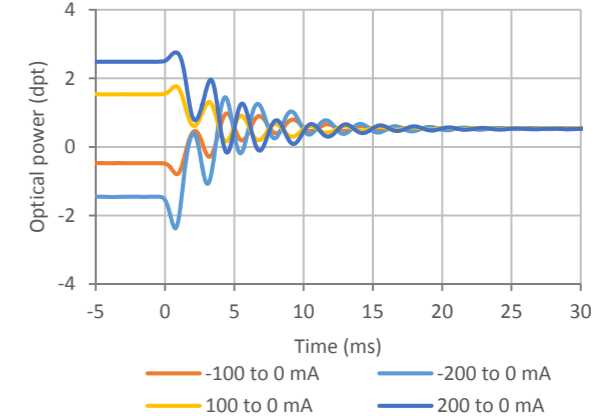
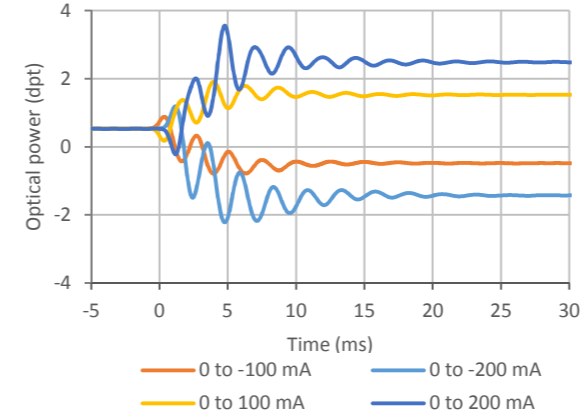
EL-16-40-TC OEM version



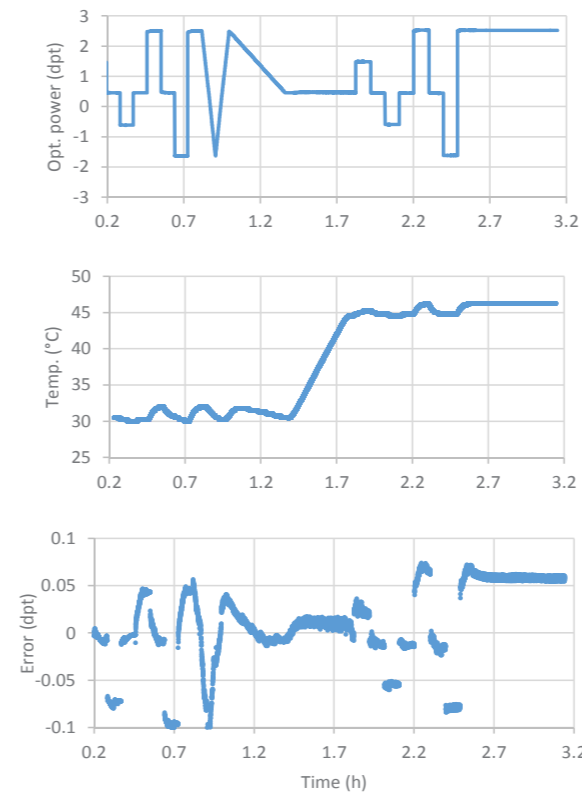
EL-16-40-TC industrial version



Response times in the millisecond range



Long term reproducibility within +/- 0.1 dpt



The optical power is varied in different patterns, e.g. large and small steps, fast and slow ramps. The x-axis represents the time in hours, as for the other plots.

After about 1.5 hours, the temperature is increased by 15°C to 45°C.

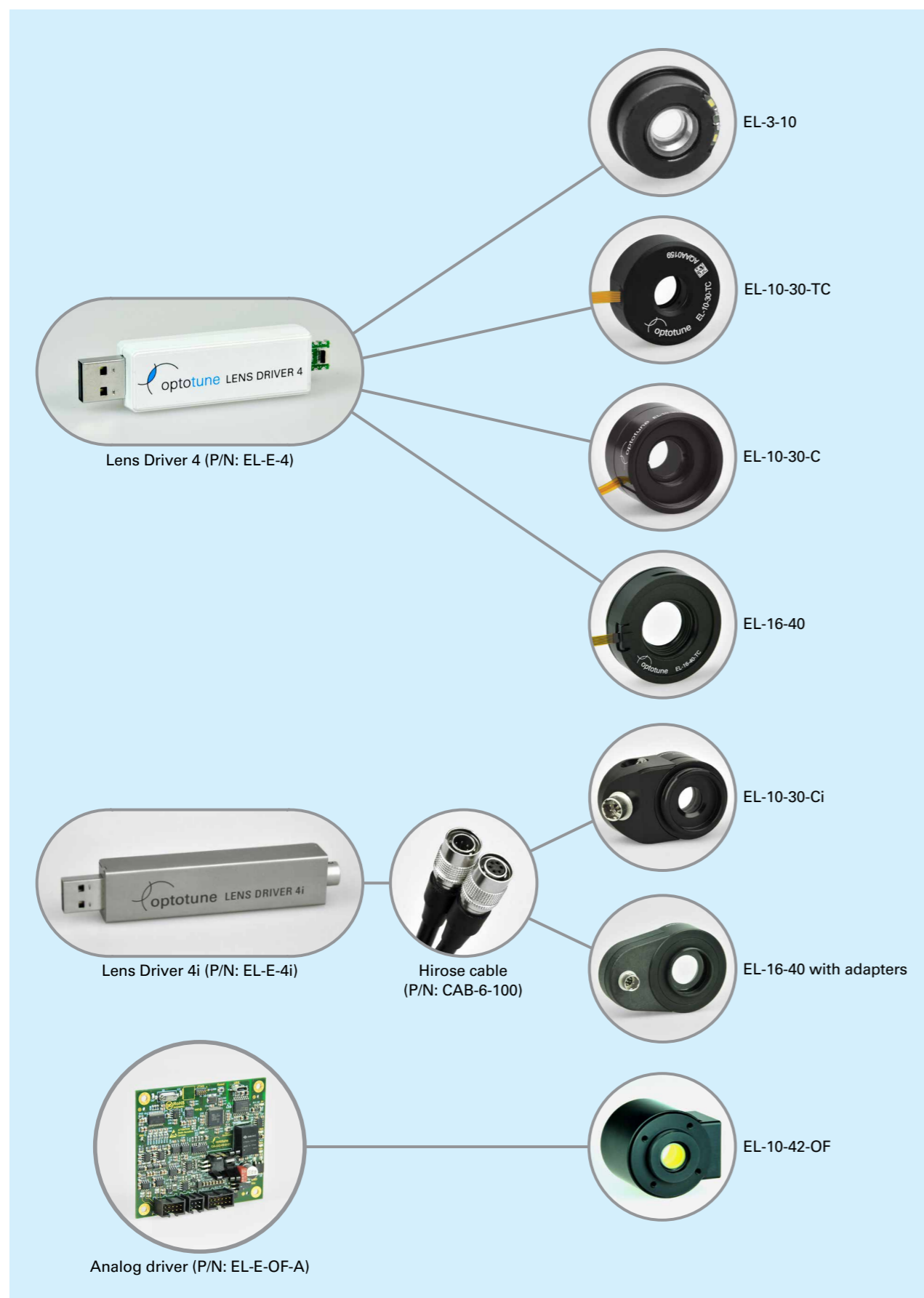
The error of optical power represents the repeatability and is the difference between measured and set optical power. The repeatability remains within +/- 0.1 dpt.

Standard Product*	Tuning range	Top thread	Bottom thread
EL-16-40-TC-VIS-5D	-2 to +3 dpt	None	None
EL-16-40-TC-VIS-20D	-10 to +10 dpt	None	None
EL-16-40-TC-VIS-5D-M25.5	-2 to +3 dpt	M25.5 x 0.5 male	M40.5 x 0.5 female
EL-16-40-TC-VIS-5D-M26	-2 to +3 dpt	M26 x 0.706 male	M26 x 0.706 female
EL-16-40-TC-VIS-5D-M27	-2 to +3 dpt	M27 x 0.5 male	M40.5 x 0.5 female
EL-16-40-TC-VIS-5D-M30.5	-2 to +3 dpt	M30.5 x 0.5 male	M40.5 x 0.5 female
EL-16-40-TC-VIS-5D-C	-2 to +3 dpt	C-mount male	C-mount female
EL-16-40-TC-VIS-5D-M42	-2 to +3 dpt	M42 x 1 male	M42 x 1 female
EL-16-40-TC-VIS-20D-C	-10 to +10 dpt	C-mount male	C-mount female

* All standard product configurations on this list are also available with NIR coating (850 - 1500 nm)

Overview of Lens Drivers

Optotune's electrical lenses are basically current controlled. While it is possible to drive such lenses with a variety of current sources, Optotune's Lens Drivers provide some important additional functionalities. By reading out integrated memory and sensors over an I2C connection, they allow for operation in the so-called "focal power mode", which allows for best reproducibility.



Lens Driver 4

Precision current source



The Electrical Lens Driver offers a simple yet precise way to control Optotune's electrical lenses. Communication with the driver is through an open serial protocol, which can be implemented in Windows, Linux or embedded systems.

There are two housing options: The EL-E-4 is intended for OEM use and comes in a plastic housing. The EL-E-4i is intended for use in industrial environments and comes in a steel housing with a self-locking Hirose connector. Both drivers allow for operation in current mode as well as "focal power mode".

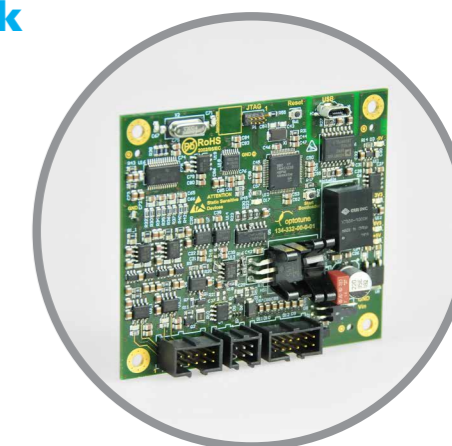
The electrical design and firmware also offer additional interfaces for analog control (0–5V input is mapped to min & max current) and UART (same protocol as through USB).

Specifications	EL-E-4 / EL-E-4i
Dimensions (L×W×H)	77×19×13 / 99.05×19×13.5 mm
Weight	11 / 41 g
Interface to PC	USB Type A
USB input voltage	5V
Maximum output current	Up to 290 mA, depending on resistance of lens
Output current resolution	4096 steps (12 bit)
Supported operating systems	Windows 7 & 10, Linux

Driver for lenses with optical feedback

Designed for laser processing applications

The EL-E-OF-A enables the control of the EL-10-42-OF lens module via an analog voltage signal from 0–5V. Several digital signals are available for status verification. The electronics essentially provide an analog-to-digital stage to read the control and set voltage signal, digital processing with an implemented PID-loop and current sources to drive the lens and the heater unit. The board is optimized for OEM-integration in laser processing systems and therefore comes without housing.



Specifications	
Dimensions (L×W×H)	85×75×30 mm (height with connector plugged)
Weight	40 g
Supply voltage Vcc	12–24 V
Lens power consumption	@ 6.5V: 0 to 3W
Heater power consumption	@ 12V: 0 to 5.76W @ 24V: 0 to 23.04W



Applications



- > Inspection of different shapes & sizes with a single system
- > Working distance changes within milliseconds
- > Combinations with standard CCTV, telecentric and zoom lenses available
- > Open loop (autofocus) and closed loop (look-up table or distance sensor) possible



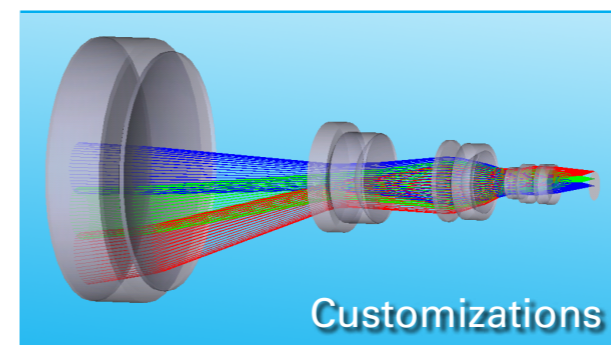
- > Fast control of z-axis
- > 2.5D & 3D laser processing with and without F-Theta lens
- > Compact, reliable design with less mechanics
- > Maximum power density of 2.6J/cm²
- > Large scan field



- > Extended range OCT to scan both cornea, IOL and retina in a single scan
- > Fast & compact focusing (e.g. in fundus cameras & slit lamps)
- > Objective refraction
- > Compact & continuous subjective refraction correction (e.g. portable phoropters)
- > Compensation of visual defects (e.g. in perimeters)



- > Axial focusing within milliseconds
- > Suitable for widefield, confocal, 2-photon fluorescent & light-sheet microscopes
- > Focal sweep 3D video imaging
- > Fast and simple image stacking



- > R&D team of over 30 engineers
- > Optical design with Zemax
- > Mechanical design with Solidworks
- > Electronics & software
- > Project management following stage gate process

Machine vision



Always in focus

Advantages

- > Large working distance ranges
- > Excellent macro capabilities
- > Easier installation and remote focus control
- > Fast response times (2.5 – 15 ms)
- > High reliability (>1 billion cycles, no moving lenses)

Applications

- > Quality control (e.g. liquids, electronics, bottles, LCDs, PCBs, lens modules)
- > Bar code reading
- > Packet sorting
- > Robots
- > 3D image stacking

Configure and calculate your setup online: <http://configurator.optotune.com>

Product inspection

Focus in milliseconds, billions of times

You would like to inspect your product at different working distances? Or read 2D codes quickly no matter how far away they are? Focus tunable lenses provide a versatile and compact solution with focusing times of only a few milliseconds. As no translational mechanics are

involved, such systems are robust and achieve billions of cycles. Optotune's lenses can be combined with off-the-shelf imaging lenses by mounting them either in front or at the back. Two examples follow, many more can be found in our application notes.



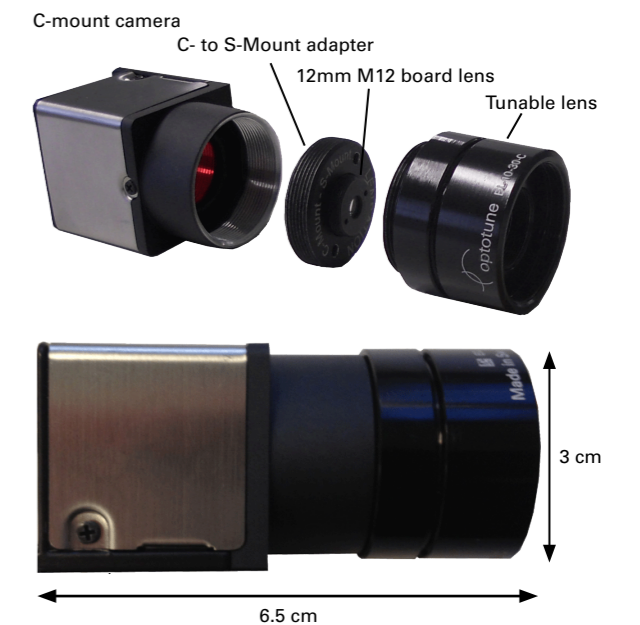
Robots with eyes wide open

Go close and re-focus to zoom in

Vision systems of 8mm to 50mm focal length can be equipped with a tunable lens in the front, typically mounted on the filter thread. In this configuration it is possible to focus from infinity (tunable lens at 0 diopters) down to about 100 mm (tunable lens at 10 diopters) or less if spacers are added.

Especially compact systems can be realized in combination with M12 board lenses, whereas the tunable lens can be mounted directly on the C-mount camera as shown on the right.

5x "zoom" example: a system with a 12mm lens and a 1/2" sensor provides a HFOV of 540 mm at 1000mm distance, useful to get an overview. At 200mm distance the HFOV decreases to 110 mm, useful for more detailed inspection.



Flexibility in logistics

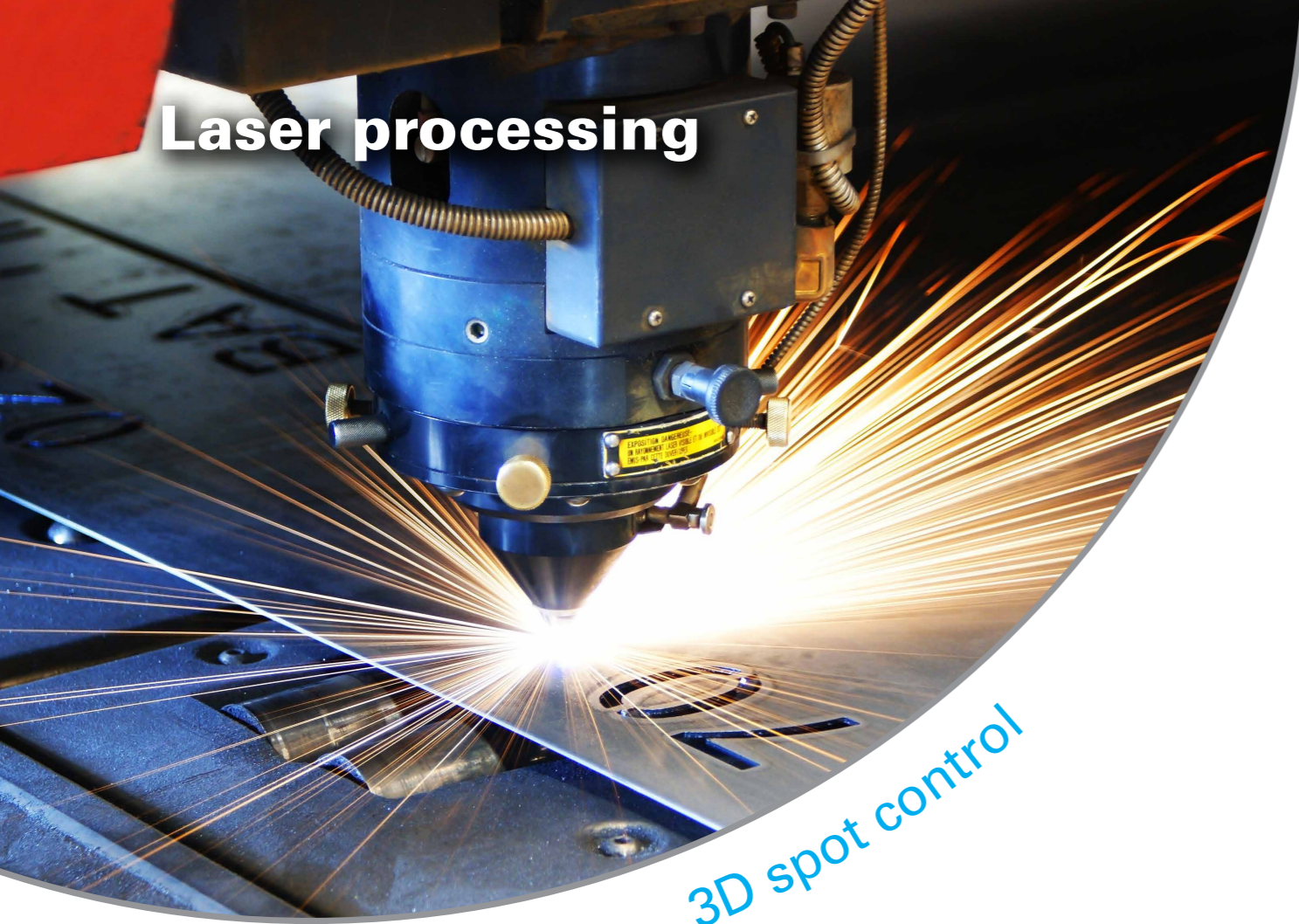
Cover a large WD-range without using additional cameras

This example is taken from a package sorting application where the working distance can be adjusted from infinity to 250 mm for each package. Optotune's EL-16-40-TC-VIS-5D-M42 is mounted at the back of a Zeiss Distagon 28mm lens with M42-mount, maintaining the sensor position at the imaging lens's flange focal distance of 45.5 mm. While high optical resolution and low distortion are maintained, additional vignetting occurs for sensors significantly larger than 1". The largest useful image circle for this configuration is 30 mm.

When placing a tunable lens at the back of a standard C-mount imaging lens (flange focal distance of 17.5mm) it acts like a spacer. The larger the distance between imaging lens and camera, the shorter the working distance. Such a configuration requires the focal length of the fixed-focus lens to be 35mm or more and is particularly suitable for macro imaging.



Laser processing



3D spot control

Advantages

- > Large scan field
- > Large z-range
- > Compact form factor
- > High speed enabling true 3D marking
- > High reliability (no moving lenses)

Applications

- > Laser marking
- > Laser cleaning
- > Laser micromachining
- > Laser microwelding
- > Laser direct structuring

Electrically tunable lens with optical feedback for 3D spot control



Precise and fast z-axis control for a large scan volume

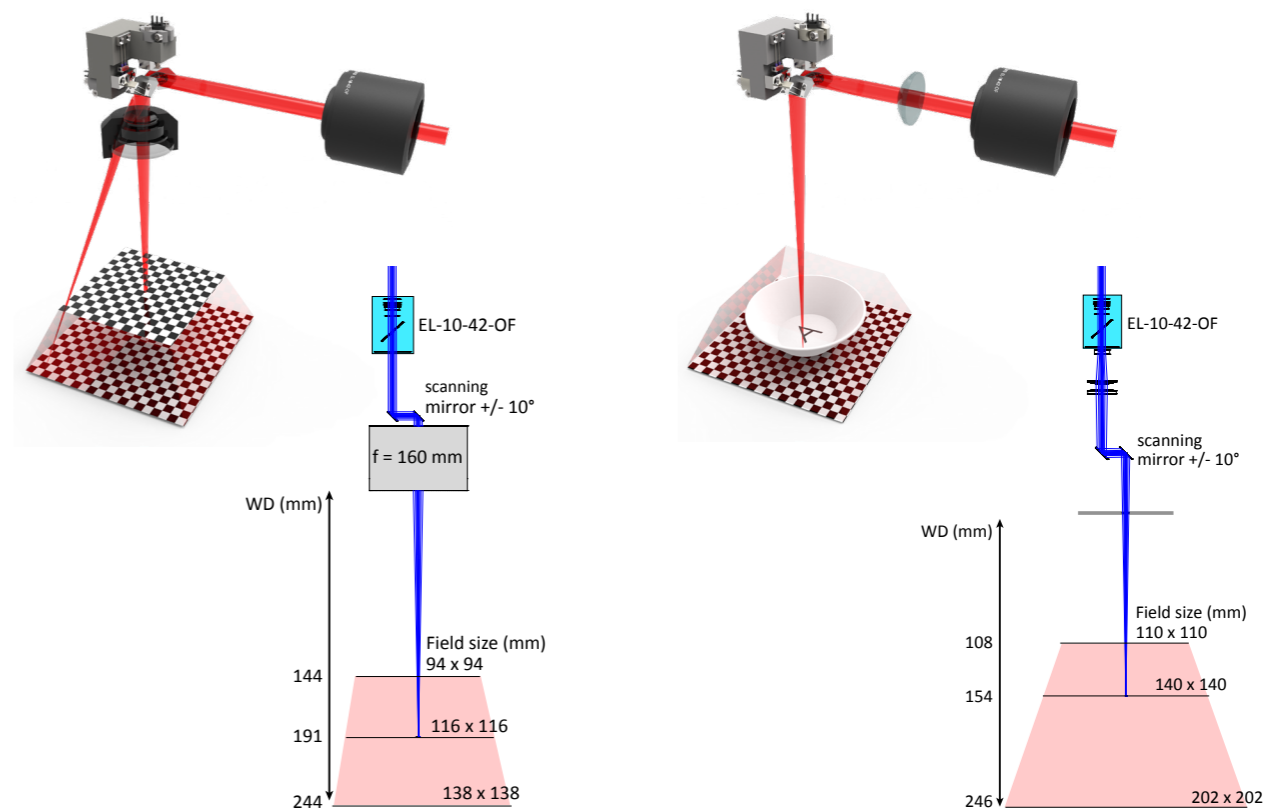
Optotune's focus tunable lens with optical feedback is the ideal choice for fast z-axis spot control in laser processing systems, allowing 2.5D and 3D laser processing. The EL-10-42-OF is suitable for the use with ns- or ps-pulsed lasers at 950 - 1100nm wavelength and power levels of up to 2.6J/cm².

2.5D laser processing

With its compact form factor, the EL-10-42-OF provides a large z-range in combination with standard f-theta lenses for flexible adjustment of the working distance. For example with an f=160 mm f-theta lens, a z-range of 100 mm is reached as illustrated below. As the field flattening is realized with the f-theta lens, an integration of the EL-10-42-OF is a fast, simple process. With an analog signal from the controller card, the EL-E-OF-A drive electronics board controls the EL-10-42-OF precisely along the z-axis, allowing to jump between large z-axis variations at high speed.

3D laser processing

When integrating the EL-10-42-OF without f-theta lens, additional fixed optics are used in combination with the tunable lens to focus the laser beam onto the processing surface. Then, the EL-10-42-OF controls the z-axis for field flattening as well as for the z-axis, providing true 3D processing. Benefits of this configuration are a larger scan field and typically better optical quality (smaller spot size) than a comparable 2D system. The comparison of two reference designs with similar maximum working distance below shows the larger scan volume without f-theta lens.



- > High jump speed between processing levels
- > Compact form factor
- > Simple analog control interface
- > Fast integration

- > Larger scan field & z-range
- > High flexibility in system design
- > Requires additional fixed optics
- > 3D laser processing software required

For the setup and optimization of your laser processing system with the EL-10-42-OF, don't hesitate to contact our sales team for technical integration and optical design support: sales@optotune.com

Ophthalmology

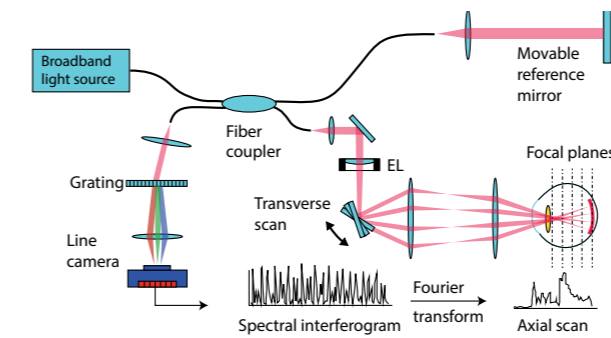


A million lenses in one

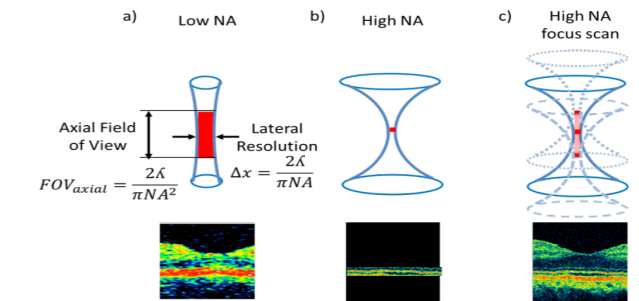
Extended Scan Range OCT

Extended OCT imaging of eye ball

With glaucoma, retinal and corneal diseases on the rise, Optical Coherence Tomography (OCT) increasingly finds its way into the ophthalmic practice. Optotune's electrically tunable lenses enable OCT systems to focus on different focal planes within the eye. It is compatible with spectral domain, swept-source and time domain OCT approaches. The fast tuning speed allows for tracking of the eyeball in real-time, leading to more reliable results. With no translational mechanics involved, the entire optics can be made compact and robust



In addition Optotune's focus tunable lens allows to overcome the tradeoff between lateral resolution and axial field of view.



Advantages

- > Extended OCT imaging of complete eye ball
- > Adjust for patient to patient variations
- > Metrology inside the eyeball
- > Extended scan range of spectral and swept source OCT
- > Higher lateral resolution

Phoropter

Ultra-compact portable module

Despite wide use of auto-refractometers, topographers and other objective refraction diagnostic tools, subjective methods such as trial lenses and phoropters remain the basis for corrective lens prescription.

A general trend is to replace expensive and bulky instruments such as the classical phoropter with



compact, portable and possibly head-worn devices. The combination of Optotune's electrically tunable lenses with two rotating cylinder lenses allows correcting spherical error and astigmatism. Optionally a tunable prism can be added. The optometrist adjusts the lens parameters from a wirelessly connected input device.

Advantages

- > Most compact way to correct refraction
- > Continuous adjustment in real-time
- > +/- 20 dpt spherical, +/- 10 dpt cylindrical
- > Extend scan range in OCT
- > Prevent accommodation (fogging)

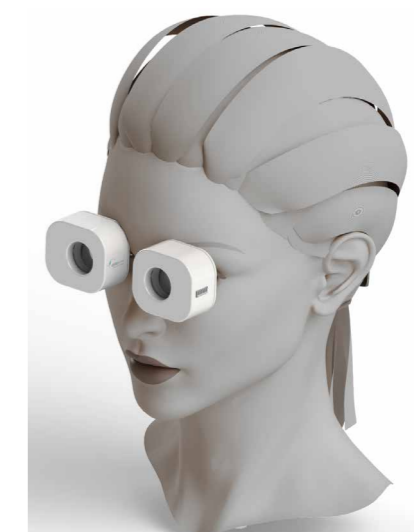
Applications

- > Phoropters
- > Autorefractometers
- > Perimeters
- > Retina imaging
- > OCT



Typical Target Specifications

Clear aperture	18-20 mm	
Spherical	-20 to +20 dpt	(0.12 dpt. incr.)
Cylinder	-8 to 0 dpt	(0.25 dpt. incr.)
Prism	0-20 Δ	(0.1 Δ incr.)
Axis of astigmatism	0-180°	(1° incr.)
Pupil distance	48-80 mm	



Microscopy



Optical z-scanning

Advantages

- > Fast z-stacking
- > Fast oscillation mode
- > Large apertures for high NA
- > Large z-tuning range

Applications

- > Wide-field microscopy
- > Confocal microscopy
- > Two-photon microscopy
- > Light-sheet microscopy
- > DNA & blood analysis

Z-scanning within milliseconds

Avoid mechanical movement by scanning optically



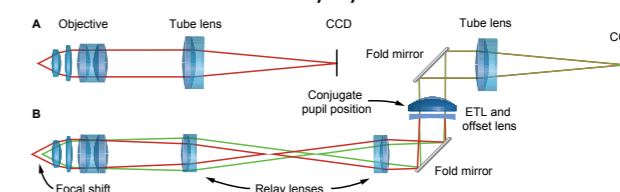
Today scientists have an increasing need to image the structures and functions of living organisms at high spatial resolution on shorter and shorter time scales.

All high-resolution 2-D imaging systems suffer from a small depth of field. Traditionally, acquiring 3-D imaging data required mechanical translation of either the objective or the sample with a stage or a piezoelectric objective Z-scanner. Because of the mechanical inertia of moving parts in such devices, achieving volume-scan rates above 10 to 20 Hz for a Z-range of hundreds of microns is highly challenging.

An alternative solution called "remote focusing" involves electrically tunable lenses to change the convergence of light as it enters or exits the microscope objective to induce an axial shift of the ex-

citation or emission focus, respectively. With their low cost, simple construction and control, and wide focus-tuning ranges, focus-tunable lenses are especially well suited for microscopy applications demanding fast volume sampling at moderate resolution.

The simplest way is to place the tunable lens inside the lens tube between infinite-corrected objective and tube lens. This leads, however, to a change in magnification. A better option is to create a pupil-position conjugate to the microscope objective with a custom-built relay system.



Confocal microscopy

Fast, precise, large volume

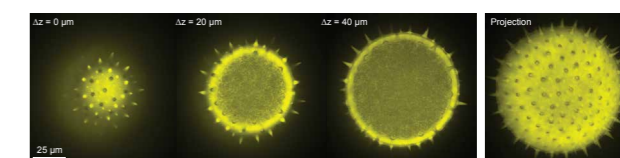
One of the most important microscopy techniques is confocal microscopy, with its large variety of applications in cell biology, single-molecule physics and many other disciplines.

Depending on the specific microscope, different solutions of inserting the electrically tunable lens are possible. One possibility is to mount the tunable lens in a custom filter cube in the filter turret of the microscope stand. Alternatively, the tunable lens can be mounted in a relay system between the confocal scan unit and the microscope stand.

A group of University of Zurich integrated an elec-

trically tunable lens into the filter cube of a commercial spinning-disk confocal microscope module.

With a 40x objective and 1.3 NA, a maximum Z-range of 60 μm was achieved. A confocal 3-D image of a pollen corn is shown below

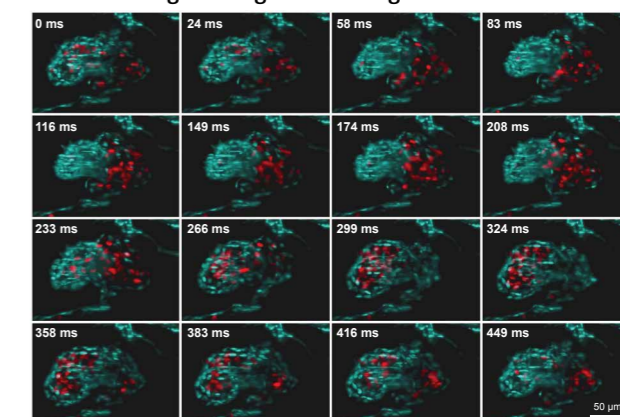


Light-sheet microscopy

Versatile 3D microscopy at moderate cost

Within the past decade, light-sheet microscopy or selective plane illumination microscopy (SPIM) have become recognized as ideal tools for in vivo imaging of biological specimens. In SPIM, the sample is illuminated from the side with a light sheet to restrict the excitation of fluorescence to a single plane in the focus of a microscope objective. SPIM offers excellent optical sectioning, low phototoxicity and high image acquisition speed. Recently a SPIM setup has been equipped with an EL-10-30 for fast volume scanning. The use of cameras running at hundreds to thousands of frames per second enabled the acquisition of 10 to 20 planes of a beating zebra fish heart at an unprecedented rate of 30 to 60 volume scans per second. Such high

volume rates allow the tracking of single red blood cells flowing through a beating heart.



Sales and support around the globe



Optotune offices

● Optotune Switzerland AG
sales@optotune.com

● Optotune Korea
daniel.lee@optotune.com

● Optotune Taiwan/China
yu-chen.sun@optotune.com

Sales partners

- Edmund Optics Inc.
www.edmundoptics.com
- Qioptiq Photonics GmbH
www.qioptiq.com

North America

United States

- Pacer USA
info@pacer-usa.com
- 1stVision, Inc.
info@1stvision.com
- Pyramid Imaging, Inc.
sales@pyramidimaging.com
- Keystone Automation
www.keystoneautomation.com
- Systems Integrators LLC
info@syintegrators.com

Mexico

- Infaimon
infaimon.mx@infaimon.com

South America

Brazil

- Infaimon
infaimon.br@infaimon.com

Europe

● STEMMER IMAGING GmbH
info@stemmer-imaging.com

United Kingdom

- Pacer International
info@pacer.co.uk

Scandinavia

- Optonyx AB
info@optonyx.com

France

- Optoprim SAS
info@optoprim.com

Spain, Portugal

- Infaimon S.L.
infaimon@infaimon.com

Hungary

- Sanxo-Systems Kft.
info@sanxo.hu

Israel

- Prolog Optics
info@prologltd.com

Italy

- IMAGE S S.p.A.
sales@imagessa.it

Asia

China

- Purple Berry Instrument Inc.
info@purpleberry.cn
- Heidstar Co., Ltd.
sales@heidstar.com
- Pixoel Technology Co., Ltd
sales@pixoel.com
- LUSTER LightTech Co., Ltd
pengfeili@lusterinc.com

Japan

- Opto Science, Inc.
info@optoscience.com
- Daitron Co., Ltd
koinuma@daitron.co.jp

Korea

- UniOTech
sales@uniotech.kr
- IOVIS CO., LTD.
sales@iovis.co.kr

Southeast Asia

- iSolutions Technology Pte. Ltd.
sales@isolutions.com.sg
- JM Vistec System Pte Ltd
info@jm-vistec.com

Taiwan

- Onset Electro-Optics Co., Ltd.
sales@onset-oo.com
- Sure Technology Corporation
sureinquiry@surevision.com.tw

