Focus Tunable Lenses for Faster and More Flexible Inspection

Mark Ventura
Vice President Sales & Marketing
Optotune Switzerland AG
• Introduction
• How to combine ELs with off-the-shelf optics
• Application examples
• Electrical integration
• Software
• Available products
Working Principle Based on Membrane and Fluid

Videos available on www.optotune.com
Tunable Lenses Offer a Natural Focusing Solution

**Fixed focus optics**
- Image sensor
- Lens with fixed focal length
- Working range limited by depth of field

**Optotune approach**
- Image sensor
- Larger lens with variable focal length
- Increased working range
  - 5cm to infinity

**Benefits**
- Larger working distance range
- Faster recognition
- Less lighting required thanks to smaller F#
- Easier installation
Focus Tunable Polymer Lenses Are Fast

Figure 12: Typical optical response of the EL-10-30-C to a current step.

Figure 13: Typical frequency response of the EL-10-30-C with current oscillating from 50 to 150 mA.

150 Hz focus oscillation  ➞ fast image stacking

Low-pass filtered step:
Demonstration Video

Optotune at Vision Stuttgart 2016
Agenda

- Introduction
- How to combine ELs with off-the-shelf optics
  - Application examples
  - Electrical integration
  - Software
  - Available products
Three Main Configurations for Machine Vision

**Front-lens configuration**
- Mounted on filter thread (adapter might be required)
- Working distances typically from infinity to 100mm

**Back-lens configuration**
- Tunable lens acts like a distance ring
- Easy mechanical solution (C-mount)

**High magnification**
- Works best with infinity corrected lenses
- 1x to 40x magnification

**Most versatile configuration**

**Best quality for short working distances**

**Best for high magnifications**
Front-lens Configuration for Large Working Distances

- C-mount camera
- C- to S-Mount adapter
- 12mm board lens
- EL-10-30-C-VIS-LD-MV

Working distance ranges from infinity to about 100mm

- EL-16-40-TC-VIS-5D-M25.5
- M27
- M30.5
Large FOV for Small Sensors with 7.2mm S-mount Lens & EL-16-40-TC

- C-mount camera with up to 1/2.3” format sensor
- Inside:
  - S- to C-mount adapter
  - Lensation B10M7224 7.2mm S-mount lens
  - 15mm C-mount spacers
  - EL-16-40-TC-VIS-5D-C

~160 lp/mm
→ Suitable for 2um pixel size!

Example for short WD

53° HFOV with 1/2.5” sensor
Back-lens Configuration for C-mount Lenses for Macro Imaging

C-mount camera

Optotune lens
EL-10-30-Ci-VIS-LD-MV
or
EL-16-40-TC-VIS-5D-C

50mm lens
e.g. Tamron 23FM50SP

### Results

<table>
<thead>
<tr>
<th></th>
<th>EL-10-30</th>
<th>EL-16-40</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>50mm lens focus</td>
<td>∞</td>
<td>∞</td>
<td>mm</td>
</tr>
<tr>
<td>Magnification</td>
<td>0.4x</td>
<td>0.4x</td>
<td></td>
</tr>
<tr>
<td>WD @0dpt</td>
<td>160</td>
<td>200*</td>
<td>mm</td>
</tr>
<tr>
<td>Z range</td>
<td>25</td>
<td>40*</td>
<td>mm</td>
</tr>
<tr>
<td>HFOV @0dpt on 1/2” sensor</td>
<td>18</td>
<td>20</td>
<td>mm</td>
</tr>
</tbody>
</table>

This only works for lenses with focal length >= 35mm

*280-420mm WD possible with Schneider Kreuznach Topaz 50mm & custom adapter
Image Circles of 30mm Possible

- WD range: from 1100mm to 380mm @ -2Dpt to 3Dpt
- Distortion unchanged
- Resolution equally good
- No added vignetting

13mm of spacers M42x0.1
EL-16-40-TC-VIS-M42
8mm spacer
Apo-Componon 60mm lens

Without EL
With EL-16-40

F4
F8

30mm

Test report available online: http://www.optotune.com/applications/machine-vision
Note: Infinite focus is possible by using only 8mm instead of 13mm of spacers at the back.
Low Distortion 1x Solution For Large Sensors

- Large z-range of 57mm achieved with +/-2 dpt
  - Optical leverage is ~14mm per diopter
- Magnification changes slightly with 0.5% per mm of WD change
- Slight vignetting at F4, no vignetting at F5.6 or higher
- No distortion measurable at 0 dpt and 1 dpt
- Nominal resolution of ~64lp/mm is maintained after adding EL-16-40 when optical axis is vertical
- In Horizontal optical axis a resolution of ~57lp/mm can be achieved by stopping the lens down to F11

95mm of M42 spacers
EL-16-40-TC-VIS-5D-M42
11m long M42 spacer
M39 to M42 adapter
Apo Rodagon D1x 75mm F/4 lens*

Test report available online: [http://www.optotune.com/applications/machine-vision](http://www.optotune.com/applications/machine-vision)

* by Linos (formerly Rodenstock)
Kowa 35mm Lens for 1” Sensors with Great MTF

Optimized optical design provides top performance

- 1” camera sensors
- F5.6 to F32 (lower F# achievable with EL-16-40-TC)
- WD range: 250 – 500mm (250 – infinity achievable with EL-16-40-TC)
- MTF50 @ 80 – 120lp/mm
- No orientation dependence

Test report: www.optotune.com/images/products/Optotune 35mm imaging lens for 1inch sensors.pdf
Telecentric Lenses Preferably Integrate the EL to Achieve Large Z-ranges

Moritex MML1-ST150D with integrated EL-16-40
- 15mm Z-range
- <5% mag change

Moritex MML2-HR110 with integrated EL-16-40
- 5.5mm Z-range
- <8% mag change

Std back-lens configuration
\[ OL \approx 0.5 [mm/dpt] / PMAC \]

New SILL lenses

\[ 1x \quad 2x \quad 10x \]
Optimized 2X Telecentric Lens for Large Formats

Tubes:
• M42 tube required for large format sensors
• C-mount tube ok for sensors up to 20mm in diagonal (as shown)

Optotune EL-16-40-TC

Sill Optics Correctal T/2.0

• 30mm image circle
• Large WD range: 105 +/-5mm
  – EL tuning from -2 to +3 dpt
• 4.5% mag change over full range
• Resolution close to diffraction limit reaching 90lp/mm

Autofocus for High Magnification

Results:

<table>
<thead>
<tr>
<th>Magnification</th>
<th>1.1x</th>
<th>3.5x</th>
<th>7.9x</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z range</td>
<td>400mm</td>
<td>40mm</td>
<td>8mm</td>
</tr>
<tr>
<td>Z resolution</td>
<td>100µm</td>
<td>10µm</td>
<td>2µm</td>
</tr>
<tr>
<td>DOF (approx.)</td>
<td>1mm</td>
<td>0.3mm</td>
<td>0.1mm</td>
</tr>
<tr>
<td>HFOV</td>
<td>4.5mm</td>
<td>1.4mm</td>
<td>0.65mm</td>
</tr>
</tbody>
</table>

- C-mount camera 1/2.5” 5MP sensor
- 1.5x mini tube lens P/N 29-90-28-000
- Optotune lens EL-10-30-Ci-VIS-LD-MV
- Optem 70XL zoom (0.75x-5.25x) P/N 399510-309
- Coaxial lighting unit with lens P/N 296515-310
- LED ring light (used instead)
- Working distance: ~90mm

- No vignetting
- Off-the-shelf components

Optem® is a registered trademark of Qioptiq, Inc
Low Cost AF Microscope with Fixed Mag

- C-mount camera
- Empty C-mount tube, 40-60mm long
- Optotune lens EL-10-30-Ci-VIS-LD
- M22 to C-mount adapter
- 25mm lens (reversed!)
  Edmund Optics 85358
- Working distance: ~20mm

<table>
<thead>
<tr>
<th>Tube length</th>
<th>40mm</th>
<th>60mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification</td>
<td>3X</td>
<td>4X</td>
</tr>
<tr>
<td>Z-range:</td>
<td>~3mm</td>
<td>~2mm</td>
</tr>
<tr>
<td>Resolution*:</td>
<td>3.7um</td>
<td>2.8um</td>
</tr>
<tr>
<td>Image circle</td>
<td>25mm</td>
<td>25mm</td>
</tr>
</tbody>
</table>

*Line width of group 7 element 4
What We Need to Make a Recommendation

1. Field of view (FOV) on object (mm in X & Y)
2. Z-range on object (distance to focus over)
3. Constraints in minimum or maximum WD
4. Desired sensor size & resolution
5. F# (if relevant)

Calculations

Overall focal length:
\[ f = \nu \times \frac{D}{V} \]

Optical leverage of EL:

Recommendation

Optical configuration:
- Off-the-shelf lens
- Optotune EL selection
- Spacers
- Thread adapters
Online Lens Configurator for Endocentric Lenses

http://configurator.optotune.com
## Configuration Table

<table>
<thead>
<tr>
<th>Sensor format &amp; camera</th>
<th>Imaging lens focal length (mm)</th>
<th>Front lens configuration only</th>
<th>Back lens configuration only</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>1/4”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-mount</td>
<td>30° HFOV</td>
<td>23°</td>
<td>15°</td>
</tr>
<tr>
<td>C-mount</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/3”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-mount</td>
<td>44°</td>
<td>33°</td>
<td>23°</td>
</tr>
<tr>
<td>C-mount</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-mount</td>
<td>56°</td>
<td>44°</td>
<td>30°</td>
</tr>
<tr>
<td>C-mount</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/3”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-mount</td>
<td>73°</td>
<td>58°</td>
<td>40°</td>
</tr>
<tr>
<td>1”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-mount</td>
<td>74°</td>
<td>77°</td>
<td>56°</td>
</tr>
<tr>
<td>30mm diag.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M42-mount</td>
<td>128°</td>
<td>114°</td>
<td>91°</td>
</tr>
</tbody>
</table>

- **Not possible**
- **Possible with custom optics design**
- **Vignetting with off-the-shelf lenses**
- **Possible with OTS lenses**

Front lens configuration only

Back lens configuration only

*Front or back lens configuration*
Where Are the Limits?

• Aperture currently limited to 16mm

  Sensors limited to 30mm diagonal
  Wide angles are problematic (f=6mm or less)

  Aperture size

  Not suited fixed focal length lens

• Optical axis vertical: 0.05–0.15 \( \lambda \) RMS
  • Optical axis horizontal: 0.15–0.25 \( \lambda \) RMS

  Wavefront error influenced by gravity

  Most applications work well in all orientations
  Few applications require the optical axis to be vertical

Note: Wavefront error measured at 525nm over 80% of clear aperture
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• Electrical integration
• Software
• Available products
Fast Focus for Different Package Heights

- Distance sensor signal is mapped to optical power
- Stand-alone system using Gardasoft TR-CL180 lens controller
- Each package is in focus within 20ms
  → at 5m/s packages can be placed with 100mm gaps

Videos available online: [https://youtu.be/83mTQu9dPc8](https://youtu.be/83mTQu9dPc8) and [https://youtu.be/h5BUsn4UTNU](https://youtu.be/h5BUsn4UTNU)
Inspection Robot with Eyes Always Open

- Refocusing allows for 5X optical zoom with inspection robot
- Front lens configuration with 12mm S-mount lens and EL-10-30-Ci
- Driver integrated in machine vision software “Neurocheck”
Sanxo Scope: Inspection at High Resolution

- Inspection station with 10MP camera
- Driver integrated in machine vision software “Modular X”

Features:
- Click to autofocus
- Continuous focus
- Focal sweep with 3D rendering
Z-stepping Solutions for Microscopes and Industry Based on EL-10-30

Life Sciences & Scientific Imaging
Microscopy Volume Imaging Solutions

Industries & Quality Control
3D Solutions For Microscopes And Automated Vision Systems

NeoScan
Fast Volume Scanning

ThunderScan
Ultra High Speed Scanning

ZeeScan
3D Add-On for microscopes

ZeeCam
3d microscope camera

Alpha³
Light Sheet Microscope

InSight
Real Time 3D Acquisition

ZeeScope
3d measurement microscope

SmartScan
Motorless focus control

www.phaseview.com
Edmund Optics Dynamic Focus VZM with the EL-10-30-Ci-VIS-LD-MV Integrated

- Very large focus range as EL is placed close to aperture stop
- The zoom is NOT parfocal, however, as the EL is placed above the zoom

<table>
<thead>
<tr>
<th>Magnification setting</th>
<th>0.75X</th>
<th>1X</th>
<th>2X</th>
<th>3X</th>
<th>4X</th>
<th>4.5X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnification range</td>
<td>0.65X - 1.15X</td>
<td>0.9X - 1.2X</td>
<td>1.5X - 2.0X</td>
<td>2.4X - 3.0X</td>
<td>3.2X - 4.0X</td>
<td>3.7X - 4.6X</td>
</tr>
<tr>
<td>Working distance (mm)</td>
<td>20 - 101</td>
<td>20 - 100</td>
<td>54 - 90</td>
<td>75 - 90</td>
<td>82 - 90</td>
<td>84 - 90</td>
</tr>
<tr>
<td>Horiz. FOV (1/2” sensor)</td>
<td>9.8 - 5.6</td>
<td>7.1 - 5.3</td>
<td>4.3 - 3.2</td>
<td>2.7 - 2.1</td>
<td>2.0 - 1.6</td>
<td>1.7 - 1.4</td>
</tr>
</tbody>
</table>
Qioptiq Optem Fusion Industrial Microscope with EL-16-40-TC Autofocus Module

- The zoom is parfocal as the EL is placed BELOW the zoom

http://www.qioptiq.com/optem-fusion-lens, Optem® is a registered trademark of Qioptiq, Inc
Camera Phone Lens Inspection

• Goal: Find dust & scratches throughout the lens stack
• Optical setup: 1-2X telecentric with 2/3” or 1” sensor
Bottle Inspection

• Goal: Look at the bottom of bottles of different heights
• Optical setup: 35mm, front lens configuration
Finding Particles in Liquid

- Goal: Count particles in a liquid volume
- Optical setup: Many options, small DoF helps

![Stack of images with depth of field](image.png)
Large Surface Inspection (PCBs, LCDs)

- Large areas are usually not perfectly flat
- Optical setup: high-mag
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Why is Our World in Diopters?

Optical power (Dpt) is linear with current

![Graph showing linear relationship between optical power and current](image)

- Vertical offset depends on liquid fill level
- Inclination depends on membrane stiffness

Optical power can be added arithmetically

Thin lens equation:

\[
\frac{1}{f_{res}} = \frac{1}{f_1} + \frac{1}{f_2}
\]

\[
D_{res} = D_1 + D_2
\]

Simple math in front lens configuration:

\[
\frac{1}{WD_{res}} = \frac{1}{WD_0} + D_{EL}
\]

Examples:

- \(WD_0 = \text{infinity}, D_{EL}=5 \rightarrow WD_{res} = 1/5\text{m}\)
- \(WD_0 = 0.5\text{m}, D_{EL}=-2 \rightarrow WD_{res} = \text{infinity}\)
- \(WD_0 = 0.5\text{m}, D_{EL}=3 \rightarrow WD_{res} = 1/5\text{m}\)
The Focal Power of Optotune’s Lenses is Controlled by Current

\[ D = \frac{1}{f} \]

Note: This curve varies from lens to lens. However, it is reproducible once calibrated.
Focal Power Mode for Good Reproducibility

- Why it is important:
  - The focal power of our lenses drifts with temperature by 0.02 - 0.06 diopters / °C (depends on lens model)

- Typical accuracy achieved: +/- 0.1dpt

---

“Why it is important:

- The focal power of our lenses drifts with temperature by 0.02 - 0.06 diopters / °C (depends on lens model)

- Typical accuracy achieved: +/- 0.1dpt

Use focal power mode to set lens to 8 diopters

Lens characterization curve stored on lens internal memory

Temperature compensated control current to adjust lens to 8 diopters

Temp sensor with EEPROM

f=125mm (8 diopters)

Lens calibration table and temperature read by lens driver

“I need a lens with f=125mm (8 diopters)”

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Three Options to Drive Optotune’s Lenses

- Currently only USB based
- RS232 & analog interface possible for R&D (connections on PCB)
- Responsibility for performance with Optotune
  
- FW shared in compiled form only
- All interfaces can be used
- Responsibility for performance with Optotune

- Only limited FW support provided
- Focal power mode needs to be implemented
- Responsibility for performance with customer!

- Best for R&D and low volume
- Fast implementation for high volumes

Optotune Lens Driver

Our circuit on customer PCB

Customer’s own circuit

Optimized for cost & performance
## Industrial Driver with GigE Interface by Gardasoft

<table>
<thead>
<tr>
<th></th>
<th>Gardasoft TR-CL180</th>
<th>Optotune Lens Driver 4i</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current range</strong></td>
<td>-400 to +400 mA</td>
<td>-290 to +290 mA</td>
</tr>
<tr>
<td><strong>Current resolution / accuracy</strong></td>
<td>0.1 / 0.5 mA</td>
<td>0.07 / 0.5 mA</td>
</tr>
<tr>
<td><strong>Latency in current mode</strong></td>
<td>Focal power mode only</td>
<td>1-2 ms</td>
</tr>
<tr>
<td><strong>Latency in focal power mode</strong></td>
<td>1 ms</td>
<td>2-4 ms</td>
</tr>
<tr>
<td><strong>Interfaces</strong></td>
<td>GigE, RS232, Analog 0-10 V</td>
<td>USB 2.0 (UART &amp; analog* 0-5 V the PCB)</td>
</tr>
<tr>
<td><strong>Firmware features</strong></td>
<td>Oscillation modes &amp; custom waveforms with trigger-in</td>
<td>Oscillation modes with trigger out</td>
</tr>
<tr>
<td><strong>Supply voltage</strong></td>
<td>24 V</td>
<td>5 V</td>
</tr>
</tbody>
</table>

* Analog input only mapped to current, not focal power
Up to 20m of Combined Cable Length Tested

- **USB 2.0 cable**
  - 1.8m included
    - Ships with Lens Driver 4
  - 5m specified
    - According to USB 2.0 standard
  - 10m tested
    - Full performance verified
    - High quality cable required

- **Hirose cable**
  - 1m Optotune standard
    - P/N: CAB-6-100
  - 3m specified
    - According to I2C standard
  - 10m tested
    - Full performance verified
    - I2C enters clock stretching mode
    - High quality, shielded cable required
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How to Find the Right Focus

Image based autofocus
- Multiple images are acquired to find the best focus by algorithm
- Typically 10-15 frames required → 0.5 to 1 sec focus time

Preset lookup tables
- Focus positions are stored in a lookup table during calibration (teaching)
- Only one focus step required → 15ms focus time

Using a distance sensor
- Multiple distance vs focal power points are saved during calibration
- Only one focus step required → 15ms focus time

- Cheap, flexible but not 100% reliable
- Inflexible, as reliable as the focal power mode (~0.1dpt)

Flexible, quite reliable but expensive

<table>
<thead>
<tr>
<th>Product</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2 dpt</td>
</tr>
<tr>
<td>B</td>
<td>1 dpt</td>
</tr>
<tr>
<td>C</td>
<td>3 dpt</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Distance</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>100mm</td>
<td>1 dpt</td>
</tr>
<tr>
<td>200mm</td>
<td>2 dpt</td>
</tr>
<tr>
<td>300mm</td>
<td>3 dpt</td>
</tr>
</tbody>
</table>
Frequency Mode Allows for Multiple Working Distances Within One Image

Lower plane in focus
The visible barcode corresponds to the lying package.

Upper plane in focus
The visible barcode corresponds to the upright package.

Frequency feature applied
The working distance is modulated with a frequency of 35 Hz. Both the lower and the upper barcode are readable.

Note: Contrast is reduced as the two images are added/overlaid during exposure. A fast camera that acquires both images separately and image processing can be used avoid this effect.
Focus Stacking for “Hyper-focus” Images

Z-stack of e.g. 10 to 30 images*

Rendered hyper-focus image*

*Rendered with Helicon Focus 6.7.1 software from 15 pictures (offline)

*Ideally the number of frames to acquire is = Z-range / DoF
Serial Protocol Can Be Implemented by Customers

- Optotune’s Lens driver is a serial device in Windows, Linux or using RS232
  - COM port in Windows
  - /dev/ttyACM0 in Linux
- Example commands are:
  - “Start” → “Ready” (works in ASCII)
  - SetCurrent
  - SetFocalPower
  - GetTemperature
- Implementation of a 16bit CRC is required
- Optotune provides sample code in C#, Labview, Python and Halcon
<table>
<thead>
<tr>
<th>Partner company</th>
<th>Software</th>
<th>Integration features</th>
</tr>
</thead>
</table>
| **Common Vision Blox** | - Lens Driver integrated in custom release  
- Slider for Focal Power Mode  
- Auto focus function |
| **EyeVision** | - Lens Driver built in through plugin interface  
- User friendly integration of current mode  
- Auto focus function |
| **Halcon** | - Lens Driver integrated via HDevelop procedure library  
- Source code can be edited  
- Image stacking & 3D reconstruction |
| **Matrox** | - C++ project compatible with MIL10  
- Auto focus implementation incl. “continuous mode” |
| **Modular X** | - Lens control via DLL calls  
- Several autofocus functions incl. “continuous mode”  
- Image stacking & 3D reconstruction |
| **NeuroCheck 6.1** | - Lens control via plugin-DLL  
- Optical power mode  
- Parallel use of several lenses |
| **nVision** | - Complete integration of all Driver features |
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# Optotune’s Electrically Focus Tunable Lenses

<table>
<thead>
<tr>
<th></th>
<th>EL-10-30-TC</th>
<th>EL-10-30-C(i)</th>
<th>EL-16-40-TC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focal power range</strong></td>
<td>8 … 22 Dpt</td>
<td>-1.5 … +3.5 Dpt +5 … +10 Dpt</td>
<td>-2 … +3 Dpt -10 … +10 Dpt</td>
</tr>
<tr>
<td><strong>Clear aperture</strong></td>
<td>10mm</td>
<td>10mm</td>
<td>16mm</td>
</tr>
<tr>
<td><strong>Outer diameter</strong></td>
<td>30mm</td>
<td>30mm</td>
<td>40mm</td>
</tr>
<tr>
<td><strong>Wavefront quality</strong></td>
<td>&lt;0.25 / 0.5 λ</td>
<td>&lt;0.15 / 0.25 λ</td>
<td>&lt;0.25 / 0.5 λ &lt;0.25 / 1.5 λ</td>
</tr>
<tr>
<td>RMS @525nm**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Absolute focal power accuracy (typical)</strong></td>
<td>&lt; 0.1 dpt</td>
<td>&lt; 0.1 dpt</td>
<td>&lt; 0.05 dpt</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Microscopy</td>
<td>Machine vision</td>
<td>Machine vision Ophthalmology</td>
</tr>
</tbody>
</table>

* Depends on selected optical fluid

** vertical / horizontal optical axis

***Qualification is ongoing
EL-16-40 with Versatile Configurations

- Two optical configurations:
  
  | Thin membrane (+/- 10 diopters) | EL-16-40-TC-VIS-20D |
  | Thick membrane (-2 to 3 diopters) | EL-16-40-TC-VIS-5D |

- Push/pull design (convex/concave lens)
  - No need for offset lens

- Several mechanical configurations:
  - C-mount (male & female)
  - M42-mount
  - Filter threads (M25.5, M26, M27, M30.5)

- Adapter threads can rotate freely and be locked
Thank you!

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