Piezoelectric Deformable Mirror

# DMH40(/M)-F01, DMH40(/M)-P01 Operation Manual

2021

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# Contents

**We aim to develop and produce the best solutions for your applications in the field of optical measurement techniques. To help us to live up to your expectations and constantly improve our products, we need your ideas and suggestions. We and our international partners are looking forward to hearing from you.**

***Thorlabs GmbH***

**Warning**

**Sections marked by this symbol explain dangers that might result in personal injury or death. Always read the associated information carefully before performing the indicated procedure.**

**Attention**

**Paragraphs preceded by this symbol explain hazards that could damage the instrument and the connected equipment or may cause loss of data.**

**Note**

**This manual also contains "NOTES" and "HINTS" written in this form.**

**Please read this advice carefully!**

# 1 General Information

The Thorlabs' Piezoelectric Deformable Mirror DMH40 is used to correct distorted wavefronts that result from common sources of wavefront aberrations, such as astigmatism and coma.

The Thorlabs DMH40 Deformable Mirror consists of a piezoelectric disk with a segmented back electrode glued to a glass substrate carrying the continuous reflective surface. The segmented back electrode controls a number of independent mirror segments. Each segment area can be forced to perform a local concave or convex bending, depending on the applied voltage. Thereby the mirror can assume any desired shape to compensate for distorted wavefronts.

Besides individual or grouped segment control, the Thorlabs Deformable Mirror software provides pre-defined voltage patterns for generation of Zernike function shapes. An adaptive control algorithm based on these Zernike coefficients allows closed loop operation in conjunction with a feedback signal from our Shack-Hartmann wavefront sensors.

Each DMH40 deformable mirror has a Ø14 mm pupil and is available with one of two optical coatings: UV-Enhanced Aluminum for 250 nm to 450 nm wavelength or Protected Silver for 450 nm to 20 µm wavelength.

Compared to the Thorlabs deformable mirror DMP40, the DMH40 has a more than 2 fold larger stroke (hoisting capacity) resulting in a more than 2 fold curvature of the mirror. While, the DMP40 can tilt the mirror due to its outer arms, the DMH40 can be tilted by using a kinematic mount.

**Attention**

Please find all safety information and warnings concerning this product in the chapter Safety 52 in the Appendix.

## 1.1 Ordering Codes and Accessories

| Item# | Short Description |
|---|---|
| **DMH40-F01** | Piezoelectric Deformable Mirror, UV-Enhanced Aluminum, 14 mm Pupil Diameter, Imperial |
| **DMH40/M-F01** | Piezoelectric Deformable Mirror, UV-Enhanced Aluminum, 14 mm Pupil Diameter, Metric |
| **DMH40-P01** | Piezoelectric Deformable Mirror, Protected Silver, 14 mm Pupil Diameter, Imperial |
| **DMH40/M-P01** | Piezoelectric Deformable Mirror, Protected Silver, 14 mm Pupil Diameter, Metric |

**Recommended Accessories:**

For Closed Loop Control setups, we recommend Thorlabs Wavefront Sensors (WFS) and Microlens Arrays (MLA) that are offered in combination.

| Wavefront Sensor (WFS Item# Prefix) | Short description |
|---|---|
| **WFS20** | High Speed Shack-Hartmann Wavefront Sensor |
| **WFS30** | General Purpose Shack-Hartmann Wavefront Sensor |
| **WFS40** | Large Area Shack-Hartmann Wavefront Sensor |

Microlens Arrays:

| Microlens Arrays (WFS Item# Suffix) | Short description |
|---|---|
| **-5C** | based on Thorlabs MLA150-5C |
| **-7AR** | based on Thorlabs MLA150-7AR |
| **-14AR** | based on Thorlabs MLA300-14AR |

## 1.2 Requirements

These are the requirements for the PC intended to be used for operation of the DMH40.

### 1.2.1 Software Requirements

The Thorlabs Deformable Mirror software is compatible with the following operating systems:

- Windows® 7 SP1 and later (32-bit, 64-bit)
- Windows® 8.1 (32-bit, 64-bit)
- Windows® 10 (32-bit, 64-bit)

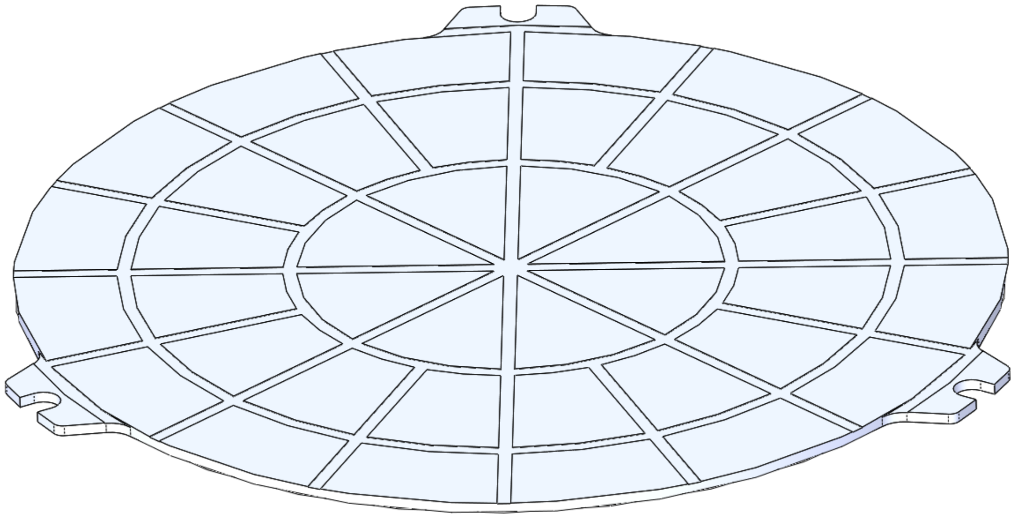
For operation of the DMH40, Microsoft® .Net Framework version 4.6.2 or higher must also be installed. This software comes with the Thorlabs Deformable Mirror software installation package, available for download on the software tab of the Piezoelectric Deformable Mirror website.

For the Control Loop 33 operation a Thorlabs Wavefront Sensor with a software version of 5.0 and later is required. For optimal performance, please use the latest software version available online.

### 1.2.2 Hardware Requirements

| | |
|---|---|
| CPU: | 2 GHz or higher |
| RAM: | 4 GB |
| Graphic card: | 256 MB memory (shared) |
| Graphic resolution: | min.: 1024 x 768; recommended: 1280 x 800 |
| Hard disk: | 1.2 GB (32 bit) / 2.6 GB (64 bit) free storage space |
| Interface: | USB 2.0 port, USB cable according the USB 2.0 specification |

# 2 Operating Principle

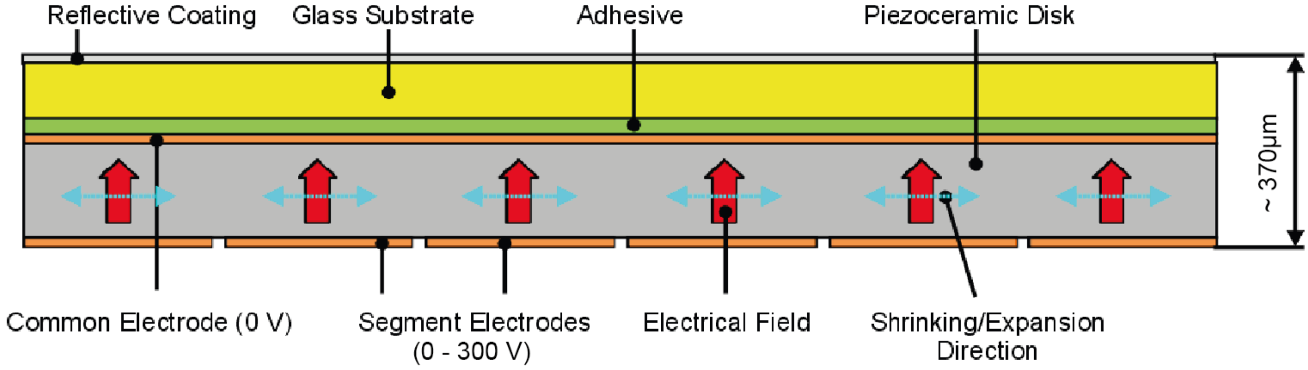


*DMH40 structure - rear view*
*showing 40 mirror segments*

The heart of the Thorlabs DMH40 is a deformable mirror. It is comprised of a glass substrate with a reflective coating that has a thin piezo ceramic disk with segmented electrodes glued to the back side.

The mirror is mounted via 3 mounting joints shown above.

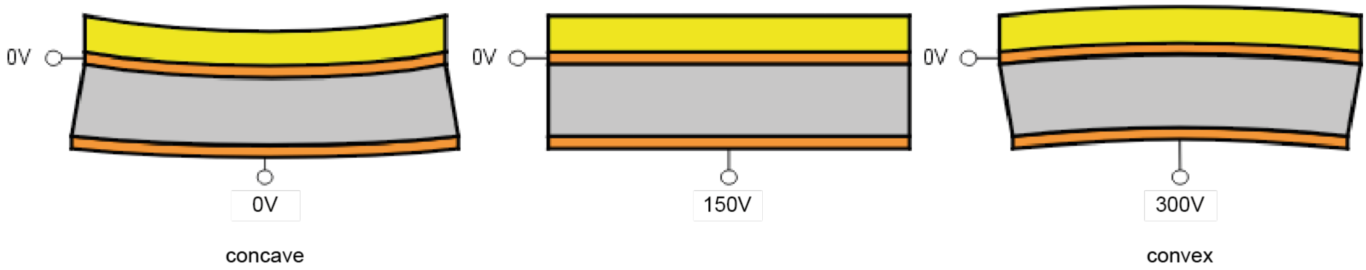
## 2.1 Mirror




*Cross section of the DMH40 inner mirror*

The above sketch shows a simplified cross section of the inner mirror. The common electrode for all segments is connected to ground (0 V), while the back side electrode is divided into 40 single segments that can be controlled individually by a DC voltage in the range 0 – 300 V each.

During the gluing process, a control voltage of 150 V is applied to all segment electrodes. For this reason, a flat mirror surface will appear at a control voltage level of 150 V, applied to all segments. At voltages <150 V, the piezo material above the corresponding electrode will expand, leading to a local concave shape, while a voltage >150 V shrinks the piezo and leads to a local convex shape:



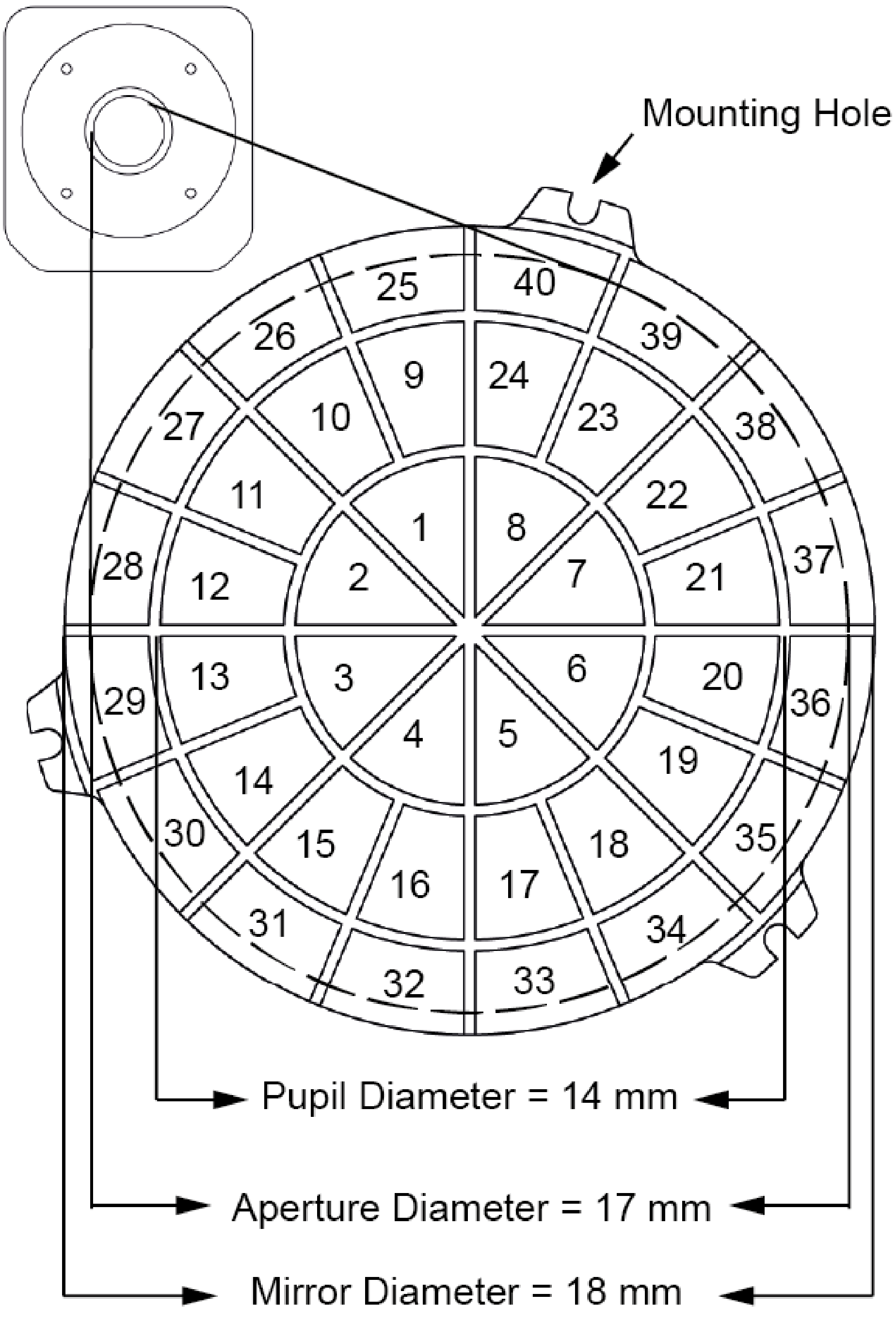

*Applying a voltage to a piezo segment*

Applying the same voltage higher or lower than 150 V to all 40 electrodes results in a pure spherical mirror shape. An arbitrary surface shape can be generated by applying a defined voltage pattern.

**Note**

The mirror will be nearly flattened after connecting it to the power supply and to a PC with the installed Thorlabs Deformable Mirror software! The reason is that the software will initialize the hardware only after PC connection is made. Whenever no power is connected to the DMH40, the mirror will be concave (0 V position).

## 2.2 Segment Structure




*View onto the mirror surface*

Electrode numbering is shown for a mirror with the reflective surface facing the viewer.

**Note**

The instrument driver software accepts zero-based segment indices in the range 0 – 39, while the user interface in the software refers to the numbering as shown in the above diagram.

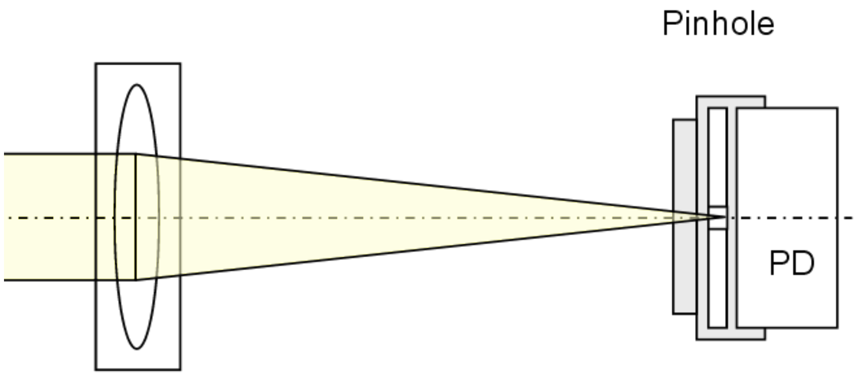
The segments 25 to 40, surrounding the mirror pupil, are used to get defined curvatures even at the pupil's rim. This improves the quality and amplitude of the Zernike terms generation.

## 2.3 Closed Loop Control

The Thorlabs Deformable Mirror software allows for closed loop control using a sensor and the DMH40 to be set up in order to achieve flat, spherical, or other wavefront shapes. Basically, there are two methods to build closed loop feedback: either by using a photo detector with the analog feedback input of the DMH40 (1) or by using a wavefront sensor feedback loop with the respective software solution (2).

**1) Analog Feedback Loop**

A part of the manipulated beam, derived from a polarization independent beam splitter, is directed via a focusing lens and a pin hole onto a photo detector (PD). The output signal of the photo detector is connected to an Analog Feedback Connector 49 (not included). This Analog Feedback Connector can then be plugged into the DMH40 analog feedback input jack. The feedback values can be used to optimize the adaptively adjusted wavefront. A simple max search algorithm can be programmed (not included in the GUI or driver) to optimize the wavefront without a wavefront sensor.




This feedback method works for 2 cases:

**a. Flat Wavefront**

If the beam focus is located exactly in the plane of the pinhole, the optical power incident on the photo detector will be at a maximum in the case of an ideally flat wavefront.

**b. Spherical Wavefront**

If the focal point is located in front of or behind the pinhole, the optical power into the photo detector will be maximized when the wavefront is spherical.

The analog feedback input (2.5 mm stereo jack) of the DMH40 provides two separate inputs dedicated to voltage and current feedback signals. The current input can be connected directly to a photodiode.

**Note**

There is no internal calibration for the current and voltage values. These are just feedback values that are suited for maximum search algorithms but not for exact measurements!

**2) Wavefront Sensor Feedback Loop**

Using the measurement results of a Thorlabs Wavefront Sensor, the Thorlabs Deformable Mirror software can control the wavefront reflected from the DMH40 according to the settings. This way it is possible to generate a flat wavefront.

The Thorlabs Deformable Mirror software uses the wavefront sensor measurement data provided via the WFS DataSocket interface (included with the Thorlabs Wavefront Sensor software).

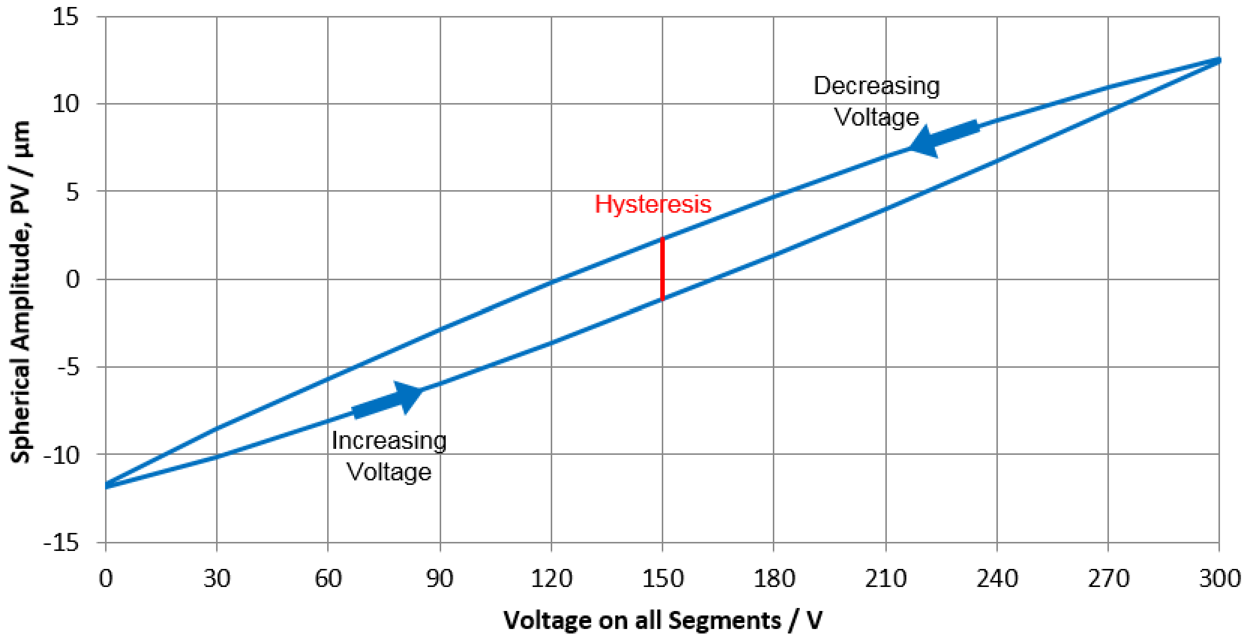
In the section Closed Loop Control 33 of this manual, this control loop method is described.

## 2.4 Hysteresis of Piezoelectric Materials

Hysteresis is a well known effect in ferromagnetic and ferroelectric materials.

Due to the hysteresis of the PZT (lead zirconate titanate) material used for the Deformable Mirror, the mirror stroke depends not only on the actual applied control voltages, but also on the "history" of recent changes. This "memory effect" is caused by internal states of the material that differ for increasing and decreasing voltages.

Due to the hysteresis effect, the mirror stroke does not follow the same track each time the control voltage is increased or decreased. The diagram below shows a typical hysteresis curve of the spherical deformation at a voltage oscillation between 0 V and 300 V (i.e., the same voltage change is applied to all 40 mirror segments).




***DMH40 Hysteresis Curve***

The hysteresis is expressed as the maximum difference divided by the maximum stroke between the two tracks. For this particular sample the hysteresis is 3.5 µm or 14% related to the total stroke range of 24.5 µm. The max hysteresis of the used material for the DMH40 is 25%.

For this reason, a control voltage of 150 V (half of the maximum control voltage) will not always produce a flat mirror (zero spherical deformation); the previous control voltage needs to be taken into account. For instance, a flat shape is achieved when the voltage is increased from 0V towards 171V and the same shape is achieved when decreasing the voltage from 300V down to 123V.

**Note**

The maximum concave and the maximum convex stroke may differ slightly as well!

**Hysteresis Compensation**

The Thorlabs Deformable Mirror software incorporates a hysteresis compensation. The driver software monitors all consecutive voltage changes for each segment individually and applies a corrected voltage, calculated based on a mathematical algorithm, to the mirror segments.

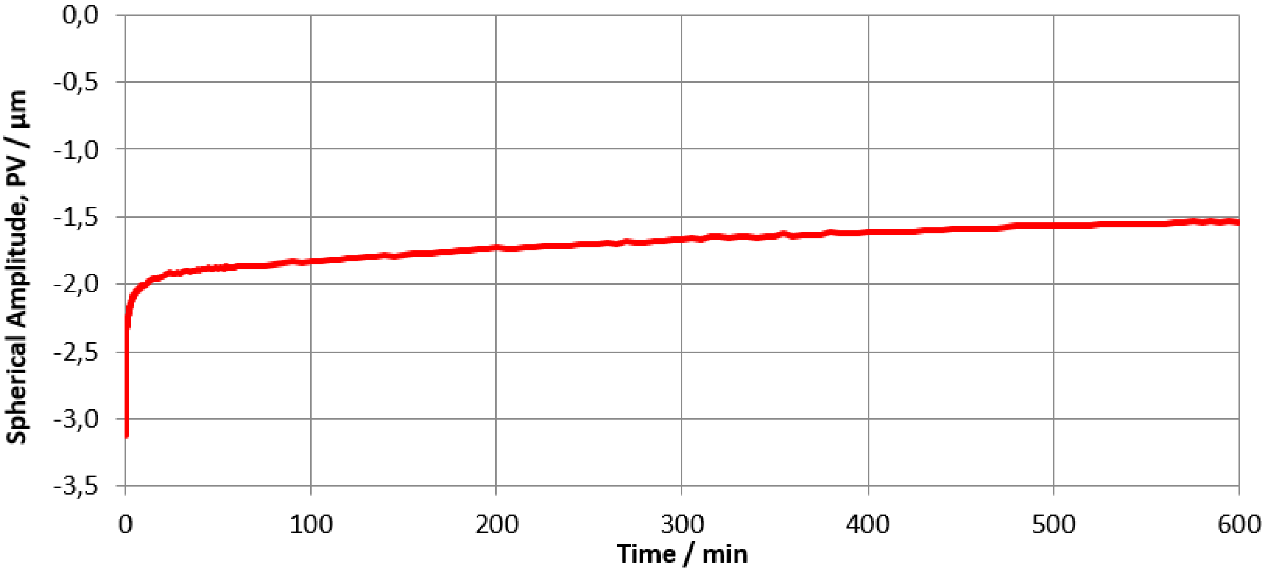
Consequently, when controlling the DMH40 via the Thorlabs Deformable Mirror software, the mirror behaves almost like a mirror without a hysteresis effect. Both tracks of the hysteresis curve will collapse to a straight line.

## 2.5 Creep of Piezoelectric Materials

The creep effect is known in material science as a slow movement or deformation of a material under the influence of an external stress.

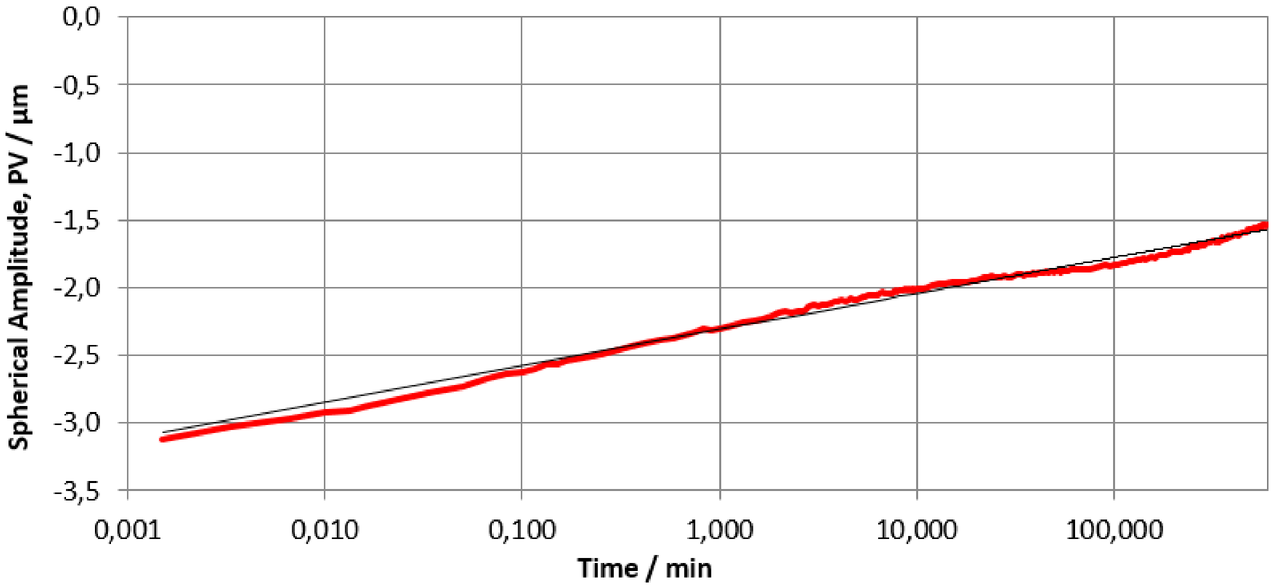
In piezoelectric materials, a creep effect is considered the continuing material expansion or shrinking after a voltage change was applied. The creep effect lets the piezoelectric material continue its mechanical change in the same direction as was induced by the last voltage step. The resulting stroke change is logarithmically dependent on time, which means that the creep speed decreases over the time, but never actually ceases.

After power-on, all DMH40 control voltages are set to 150V in order to get a nearly flat shape. Since the piezo material was at zero voltage for a long time before, the voltage step from 0 to 150V causes an immediate jump, followed by a long-term drift.




***Drift after Power-On (Linear Time Scale)***

The majority of the creep is observed within half an hour but it goes on over many hours. In logarithmic scale the drift appears as a nearly straight line:

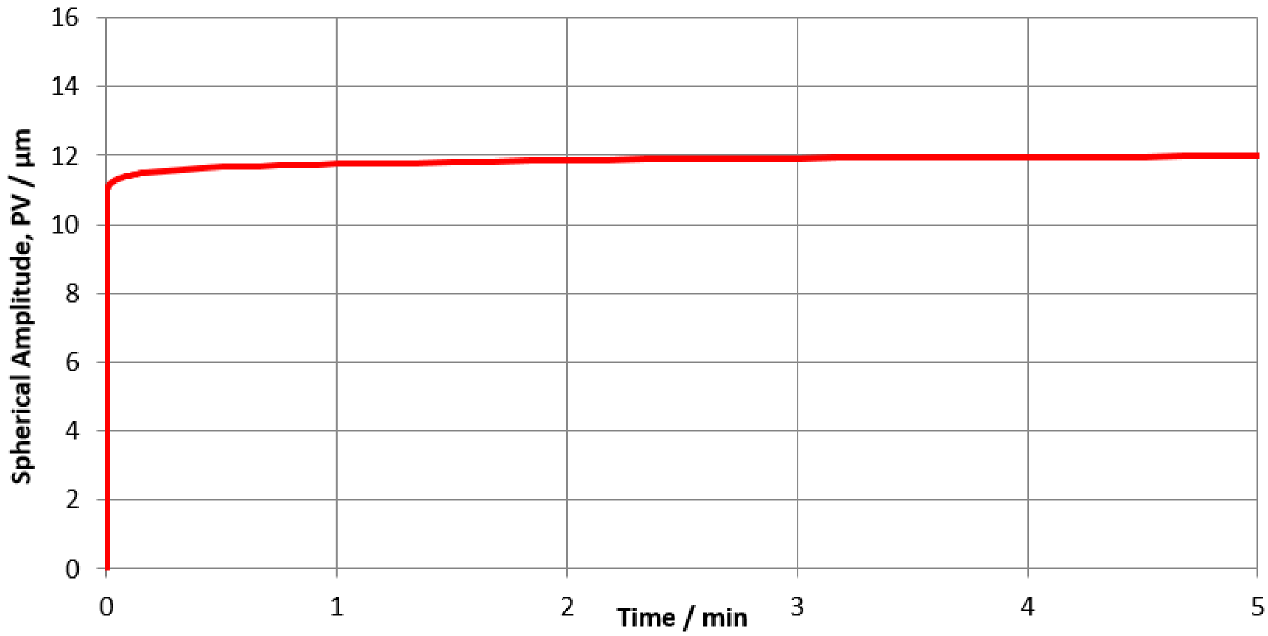



***Drift after Power-On (Logarithmic Time Scale)***

**Relaxing the Creep**

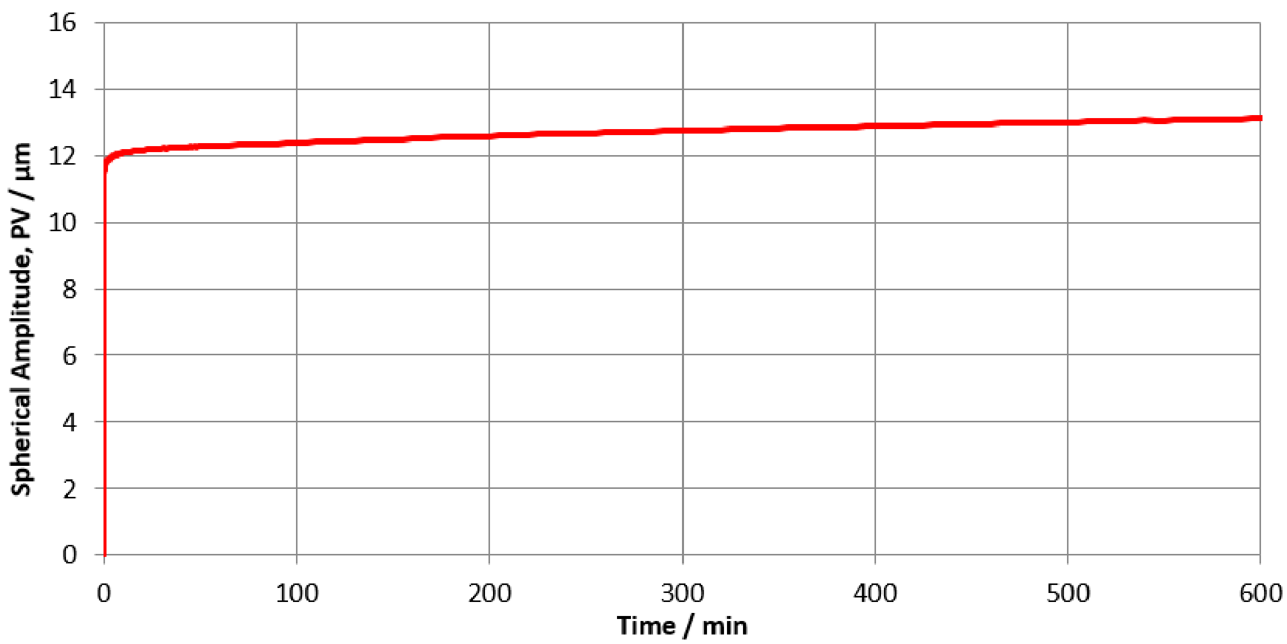
The Thorlabs Deformable Mirror software offers a Relax 12 function. By pressing the appropriate button, the control voltages of all segments are increased and decreased sequentially, starting at the full range (0 to 300 V) with subsequent decreasing amplitude, reaching at the end the mean voltage of 150 V. This way the time required to come to a stable and nearly flat mirror shape is shortened drastically.

Drift effects occur whenever the mirror's control voltage is changed. For instance, a step from 150V to 300V on all segments causes a step from zero to about 11.3 µm spherical amplitude.




***Drift after 150 V -> 300 V Step (Short Term)***

Although this 11.3 µm deflection seems to be stable after a few minutes, there is a long-term drift towards 13.2 µm after 10 hours:




***Drift after 150 V -> 300 V Step (Long Term)***

### Creep Consequences

Consider the creep effect particularly when performing adaptive correction using a feedback loop control: As long as the control loop is closed, slow drift effects of the DMH40 are corrected automatically.

As soon as the loop control is stopped, the last voltage pattern remains applied to the mirror segments, but the physical mirror shape will start a slow, continuous creep which leads to a wavefront drift.

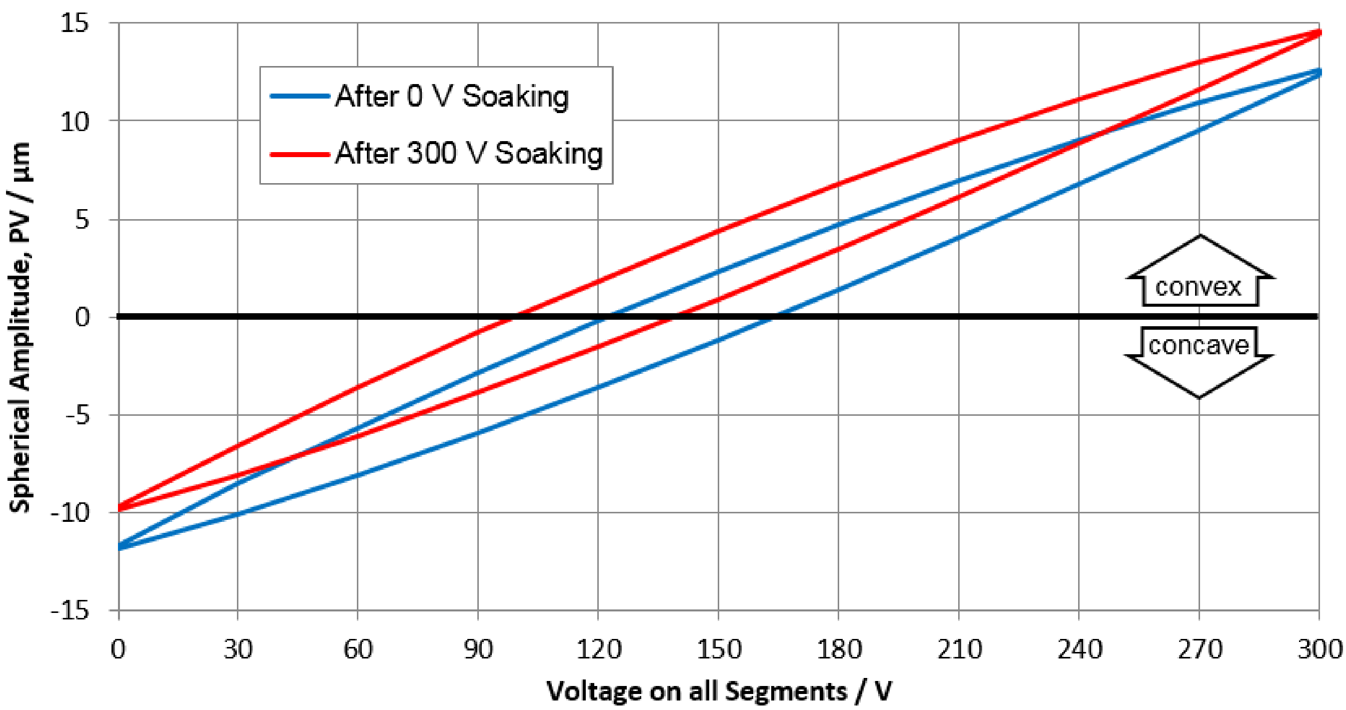
**Note**

Even if a voltage pattern that produced a defined wavefront is reproduced exactly, the original defined wavefront will not be reproduced exactly.

The Thorlabs Deformable Mirror software is not able to compensate for the creep effect. Creeping can be eliminated only within a closed loop control system. In other words, piezoelectric deformable mirrors cannot be used to exactly set a deterministic wavefront distortion.

### Shift of Hysteresis Curve

Finally, the creep overlays the hysteresis, so that the hysteresis curve will be shifted, depending on the voltage applied to all segments before measuring the hysteresis curve. The diagram below illustrates that.




***Shift of Hysteresis Curve***

The creep effect is present regardless of whether the DMH40 is switched on or off. After the DMH40 was switched-off for a long period, the hysteresis was measured. The creep let the mirror's concave shape at 0 V increase, which leads to a shift of the hysteresis curve downwards (blue curve).

Then a segment voltage of 300 V was applied for several hours. The hysteresis (red curve) is shifted by about 2.1 µm towards convex direction, equivalent to about 8% of the spherical range.

However, both hysteresis amplitudes are equal, they are just shifted.

## 2.6 Relaxing the Mirror

In the previous, chapters some essential properties of piezoelectric materials - hysteresis and creep (drift) - were described. These properties have a non-negligible impact on the control of the mirror surface by applying voltages. The resulting surface shape depends not only on the present voltage pattern, but also on the "history" of previous changes.

Example: Assume a starting condition where the mirror was flat at 150 V:

1. The segment voltage has been changed from 150 V to 300 V (maximum convexity), and then back to 150 V.
   In this case, the hysteresis' impact 8 is that after applying 150 V the mirror remains somewhat convex. The creep effect, on the other hand, makes the surface continue to move in the direction of the last adjustment: the mirror surface becomes more and more flat. If we wait long enough, it will become concave.
2. The segment voltage has been changed from 150V to 0V (maximum concavity) and then back to 150V.
   This is the opposite case: The mirror remains slightly concave due to hysteresis, and continues to flatten over time due to creep.

The effects described above are more significant, the larger the change in the applied voltage.

The Thorlabs Deformable Mirror software provides a Relax feature to eliminate or at least to minimize the above impacts. It will carry out 3 steps:

1. Remember the actual voltage pattern
2. Damped oscillation of the applied voltage symmetrically with respect to the original voltage. This means that to a segment with an initial voltage of 150V a "sequence" of 300 V - 0 V - 285 V - 15 V -... 165 V - 145 V - 150V will be applied during relax. This maximum relax amplitude will be the less the closer the initial segment voltage was to the limit (0 V or 300 V).
3. Restore the voltage pattern that was present prior to Relax

This way, the mirror is moved in both directions with decreasing amplitude so that hysteresis and creep (drift) effects will be minimized.

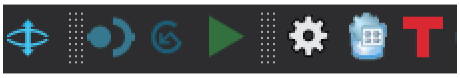
**When should the Relax be done?**

Relax is recommended to prevent recently-made large voltage changes from impacting the next experiment, e.g.:

- after starting up the software
- after applying voltage patterns and their subsequent restoration
- prior to a new experiment
- prior to starting closed loop control using a wave front sensor

**How to Relax segments**

To relax the mirror segment, click the 'Relax' button  in the tool bar.



An appropriate tool tip appears when hovering the mouse over the the the 'Relax' button.

# 3 Getting Started

Inspect the shipping container for damage. When opening the package, please do not cut through the cardboard.You might need the box for storage or for returns.

If the shipping container seems to be damaged, keep it until you have inspected the contents and you have inspected the DMH40 mechanically and electrically. Keep the container for storage or in order to return the product in case of future problems.

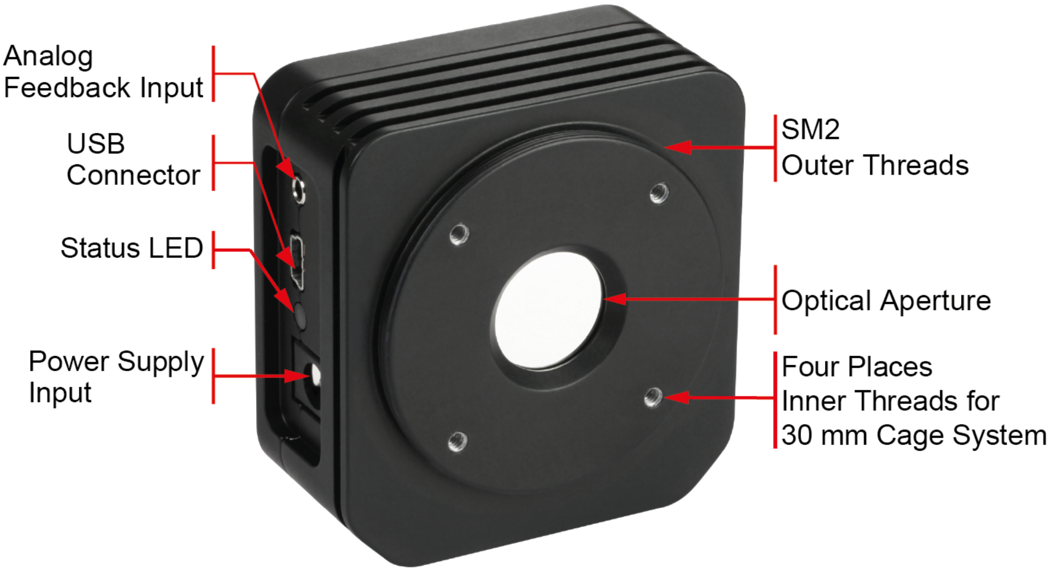
Verify that you have received the following items within the package:

## 3.1 Parts List

1. DMH40 or DMH40/M Deformable Mirror
2. SM2CP1 threaded cap
3. USB 2.0 cable A to Mini B, length 1.5 m
4. Power supply 100 to 240 V AC to 12 V / 1.5A DC
5. Power Cord
6. Quick Reference

# 4 Operation

## 4.1 Operating Elements




## 4.2 Installing Software

**Note**

Do not connect the DMH40 to the PC prior to software installation!

**Attention**

Exit all running applications on your PC as the installer may require a reboot of your PC during installation!

**Software download**

Please download the software package from the software tab of the product website. The most recent version of the software will always be available online.

Click the Software button to download the DMH40 Software ZIP archive, unpack it and open the installation folder. Double click the application setup.exe.

**Note**

Depending on your Windows® Security and User Account Control settings, warnings may appear several times during the installation process, asking to allow software installation. Please confirm that when appropriate in order to proceed with a proper software installation.

The installer checks if Microsoft® .NET Framework 4.6.2 is installed already and requires the installation of eventually missing components. An appropriate status message appears - click "Install".

Usually, the Microsoft® .NET Framework is already installed and updated during the Windows® Update process. After finishing the .Net Framework installation, the installer may require a reboot of the computer. Please do so.

After the reboot, the installer continues with installing the DMH40 software.

A Readme screen comes up with important information about the installed software.

Click **Next >** and in the next screen **Finish** to finalize installation process.

## 4.3 Mounting

**Mounting the DMH40**

The imperial version DMH40 and metric version DMH40/M each feature two different threads for mounting of the deformable mirror on a post.

To mount the DMH40, please use either a post with a 1/4-20 or 8-32 threaded setscrew, 6 mm in length.

To mount the DMH40/M, please use either a post with a M6 x 1 or M4 x 0.7 threaded setscrew, 6 mm in length.

**Mounting Optics on the DMH40**

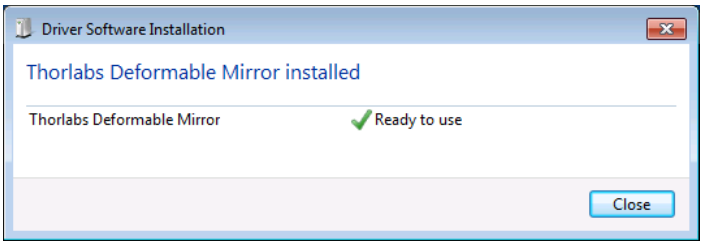
The SM2 external thread allows mounting of appropriate mounting optics or lens tubes.

To mount a Thorlabs 30 mm cage system, both DMH40 and DMH40/M offer four 4-40 inner threads with 5 mm depth on the front of the device.

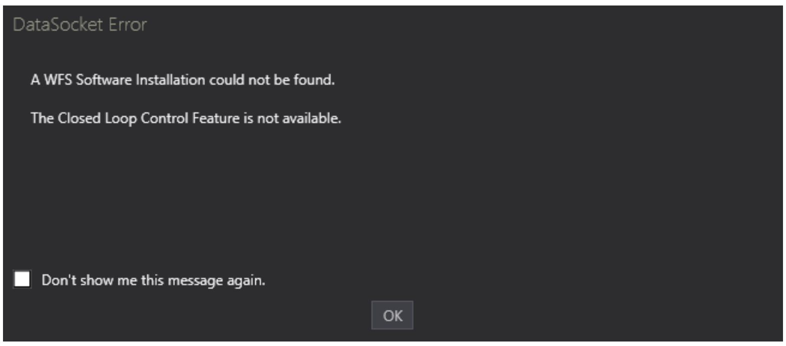
## 4.4 First Steps

After installing the Thorlabs Deformable Mirror software and mounting the DMH40 to the optical setup, proceed with the following steps:

1. Connect the power supply to the mains outlet using the provided power cord.
2. Connect the DC output of the power supply to the DC input (4).
3. Connect the USB cable to the DMH40 and to the PC. Make sure the status LED (3) lights up, first red (no DC input recognized) and finally green (ready).
4. The operating system recognizes the connected DMH40 and installs necessary software components (device driver).



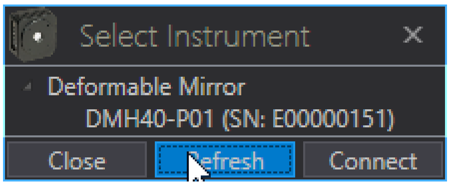

5. Start the DMH40 software from the desktop icon.
6. The application starts and automatically connects to the DMH40.
7. A warning screen may appear: DataSocket Error:



Unless you wish to use a wavefront sensor with the DMH40 to correct a wavefront as described in Closed Loop Control, please click okay. Otherwise, please install the WFS software and restart the Thorlabs Deformable Mirror software.

8. In case no Deformable Mirror was connected when the software was started, no Deformable Mirror will be recognized. In that case connect the Deformable Mirror and click "REFRESH". To connect the recognized device, select it and click "connect".




In case two Deformable Mirrors were connected to the PC, select and connect the Deformable Mirror of choice.

**Note**

Pressing the keyboard button **F1** calls up online help to the Thorlabs Deformable Mirror software.

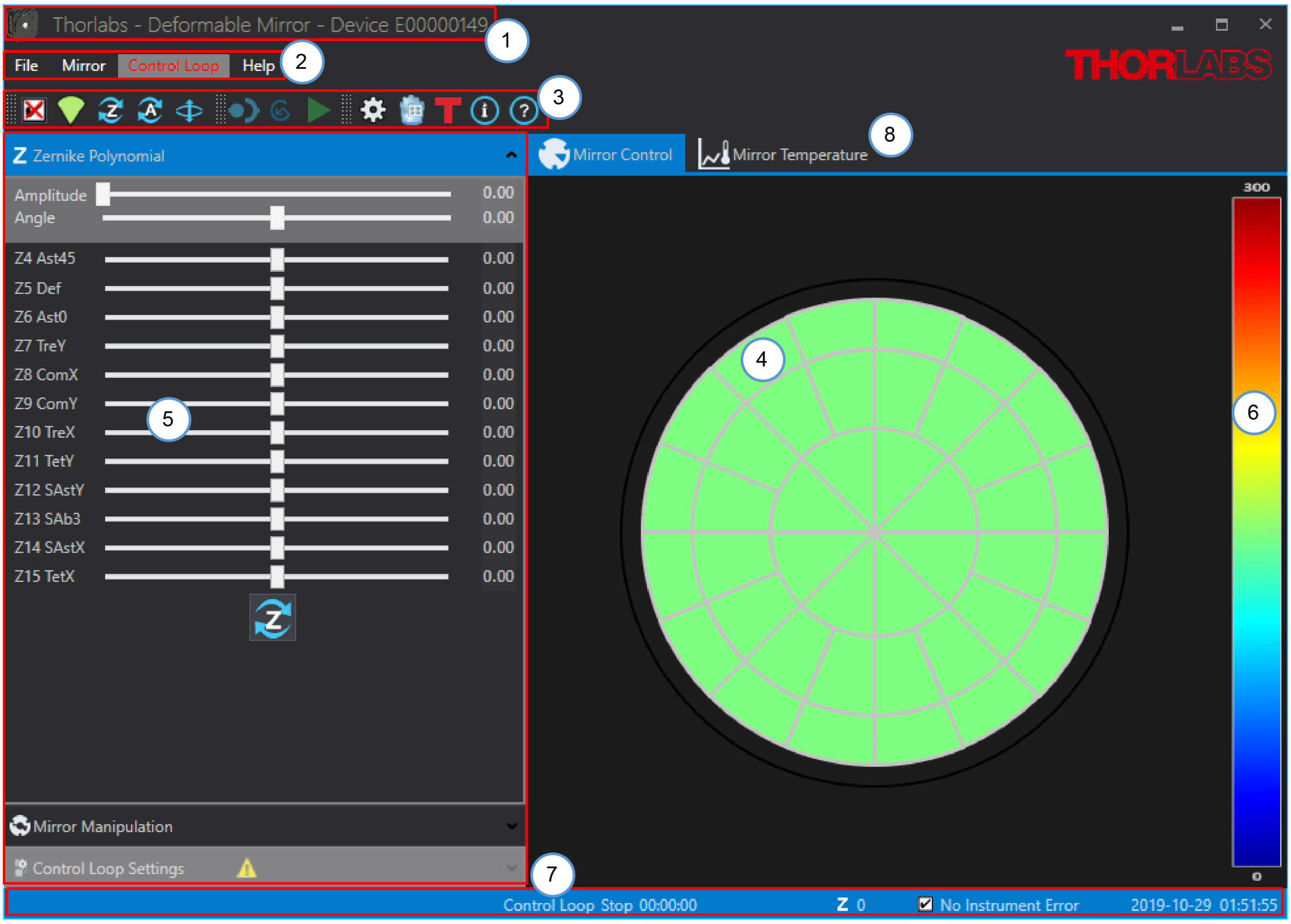
## 4.5 Out-of-the-Box Test

It is simple to test the DMH40 "out of the box". You do not need even a light source or other optical equipment - just your eyes:

- Connect the DMH40 to the power supply and to the PC with installed software.
- Start the Deformable Mirror software. The DMH40 is initialized.
- Look onto the mirror surface and change the position until you can see your eye's pupil.
- Press the "Relax" button in the toolbar and observe the diameter of your pupil. The Relax function changes the mirror segment voltages in such way that the mirror surface alternates between concave and convex, changing the diameter of the reflected pupil of your eyes.

## 4.6 Software Deformable Mirror

After connecting the DMH40 and starting the software, the default GUI window opens. When a DMP40 deformable mirror is connected, the corresponding GUI will appear (please see the manual of the DMP40).






### 4.6.1 GUI Header

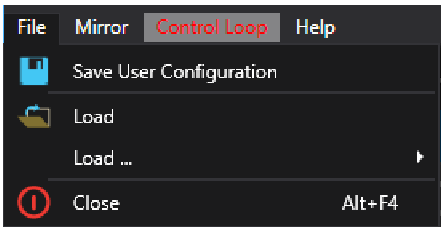
The header of the graphical user interface indicates the recognized product and its serial number by default. If the device status changes (e.g., the DMH40 is disconnected or the DMH40 power supply fails or if another Deformable Mirror connected to the PC is chosen/elected), the color turns to red and the present status is given.

For details, please refer to section Troubleshooting 43.

### 4.6.2 Menu Bar


**The FILE menu** allows you to save or load deformable mirror data.

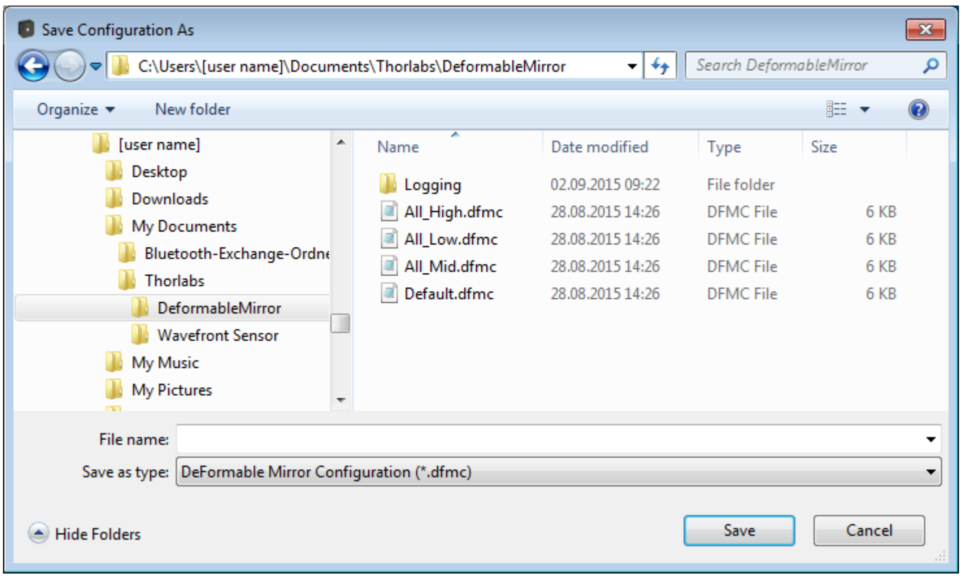



The file format is ***.dfmc** (Deformable Mirror Configuration). A configuration file is comprised of three main parts:

- General information: Information about software version, driver version and the recognized instrument
- Application settings
  - Size and position of the GUI
  - Active Control Panel 25
  - Color style 29
  - ID overlay status 19
  - Zernike pattern orientation 22
  - Control Loop settings 20 (delay, selected Zernikes)
- Data
  - Status of hysteresis compensation
  - Voltage pattern that is applied to inner mirror segments
  - Zernike slider positions

#### Save User Configuration

You can save (and restore via the **Load** function) your present configuration at any time:



Indicate a file name and click the **Save** button. This way, a configuration can be used, for example, to duplicate a setup or to save a configuration for future use.

### Load

This menu item allows any user configuration file to be loaded. With this option, all application settings and DMH40 data (Zernike slider positions and segment voltages) can be restored easily.

**Note**

With updating the Thorlabs Deformable Mirror software from older versions, the file structure of the configuration files may have changed form .dmfd to .dmfc. The .dmfd files will not readily be recognized by the new software version. Please follow the steps described in the section troubleshooting 45, loading .dmfd files.

### Load ... Data (Zernike and Voltages) Only

Using this option, only data 32 are loaded, while application settings remain unchanged. In this case, only the Zernike and voltage data are retrieved from the selected .dfmc file.

**Note** Loading data from a *.dfmc file just reproduces and applies the saved voltage pattern and Zernike positions. Due to the piezoelectric properties (see Hysteresis of Piezoelectric Materials 8 and Creep of Piezoelectric Materials 9 ), the surface shape generated by the DMH40 will not exactly reproduce the original surface shape from the previous application of these parameters!

**Note** Data reconstruction will be correct only if the settings for Flip and Rotate are the same as at the moment the data were saved.

### Load ... Settings Only

In contrast to the previous function, here only application settings 32 are retrieved from the selected *.dfmc file. Segment voltages and Zernike slider positions remain unchanged.

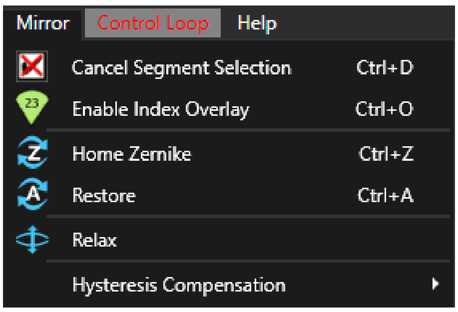
### Close

The application will be closed.

**Note**

When closing the application, all settings and data will be saved automatically.

### The MIRROR Control Menu




**Cancel Segment Selection** deselects the selected segments, see section Segment Control 24.

**Enable Index Overlay** is a toggle button to enable/disable the numbering of the mirror segments.

**Home Zernike** resets all Zernike sliders to the HOME position. Please note that manipulating Zernikes applies a voltage shift to all of the mirror segments related to this Zernike coefficient. In other words, this is a voltage offset, not an absolute voltage!

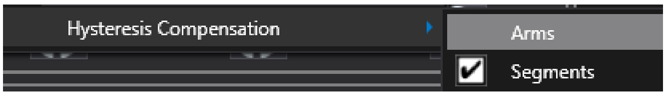
Resetting Zernike sliders to HOME position means that all Zernike coefficients are set to zero. The voltage pattern on the mirror segments is generated accordingly.

Any segment voltages that were generated by direct mirror segment manipulation 27, will remain unchanged after homing Zernikes.

**Restore** resets all Zernike sliders to the home position and the voltage of all mirror segments and arms to 150 V.

**Relax** is a function that removes mechanical tensions in the mirror. For details, please see section Relaxing the Mirror 12. Click the Relax button to relax the entire mirror.

### Hysteresis Compensation




The last topic in the **Mirror** control menu serves to enable/disable the hysteresis compensation 8 for the mirror segments. Since, in contrast to DMP40, the DMH40 does not have arms to tilt the mirror, this option is grayed out.

By default, the hysteresis compensation is enabled. However, if it is desirable to analyze hysteresis effects on the mirror shape, the hysteresis compensation can be disabled by unchecking the appropriate box.

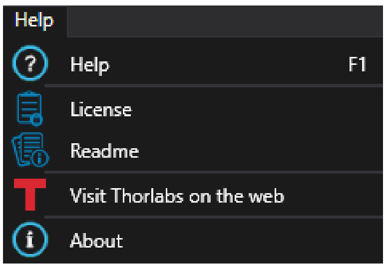
### The CONTROL LOOP Settings Menu


This menu is only enabled when a wavefront sensor is used to facilitate a control loop. This is a short menu to enable / disable the Zernike coefficients used for closed loop control. A red colored menu topic indicates that no Zernikes are selected.

Select the desired Zernike coefficients that you want to maintain ZERO during closed loop control.

In the Control Panel, tab Control Loop Settings 28, this selection can be made as well.

### The HELP Menu




The keyboard button **F1** brings up the online help at the first chapter. The search function allows to find the chapter of interest.

### 4.6.3 Toolbar

Cancel Segment Selection: Manually selected single segments 24 or groups of segments 24 are being deselected.

Toggle button to enable/disable the numbering of the mirror segments. The number indicated the enabled numbering.

Home Zernike 25: Sets all Zernike coefficients to zero. Voltage patterns on the segments resulting from manual direct mirror manipulation, will remain.

Restore: Sets all Zernike coefficients to zero and all segment voltages to 150 V.

Relax 12 the mirror

DataSocket Server Connection (toggle icon and status return)

Control Loop Parameter Determination

Enable / disable the loop control

Opens the Common Settings 22 dialog (see below)

Resets the application completely to the initial state 32 after installation.

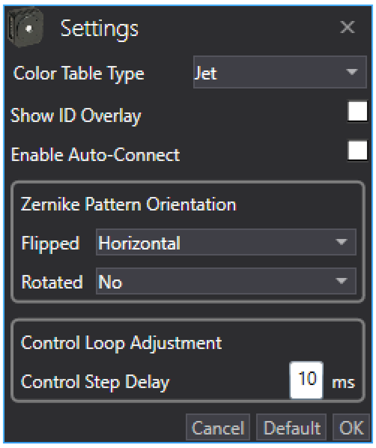
Opens the link to the Thorlabs web site

Opens the About 41 box

Opens the online Help

## 4.6.4 Common Settings




**Color Table:** There are 7 different color styles to choose from. See Color Bar 29.

**Show ID Overlay:** Check the box to display the segment indices.

**Enable Auto-Connect:** When set, the Thorlabs Deformable Mirror software automatically connects to the first Deformable Mirror that is recognized by the software after dis- and reconnecting. When the box is not checked, the user needs to choose the Deformable Mirror.

**Zernike Pattern Orientation**

The Thorlabs Deformable Mirror software calculations for closed loop control depend on the optical setup, particularly how optical elements in the optical path between the DMH40 surface and the wave front sensor influence the image orientation, or in other words the Zernike pattern orientation. Mirrors and beam splitters flip the image. Also, there may be a rotation between the XY axes of the DMH40 and the WFS. All this can be compensated manually in this menu. The pattern can be flipped horizontally, vertically, or by a rotation angle of 0°, 45°, 90° or 135°. Besides the manual correction, the Thorlabs Deformable Mirror software is able to analyze the Zernike pattern orientation automatically - please see section Control Loop Parameter Determination in the manual of the DMP40.

**Note**

Any changes that are made manually to **Zernike Pattern Orientation** in this panel will overcome the results of the Control Loop Determination results! In other words, if you change **Flip** and/or **Rotate** after an automatic adjustment was carried out, the control loop will not work correctly.

**Control Loop Adjustment**

Control Step Delay is the delay time in milliseconds between setting a Zernike pattern for loop control and retrieving the next data from the WFS via DataSocket.

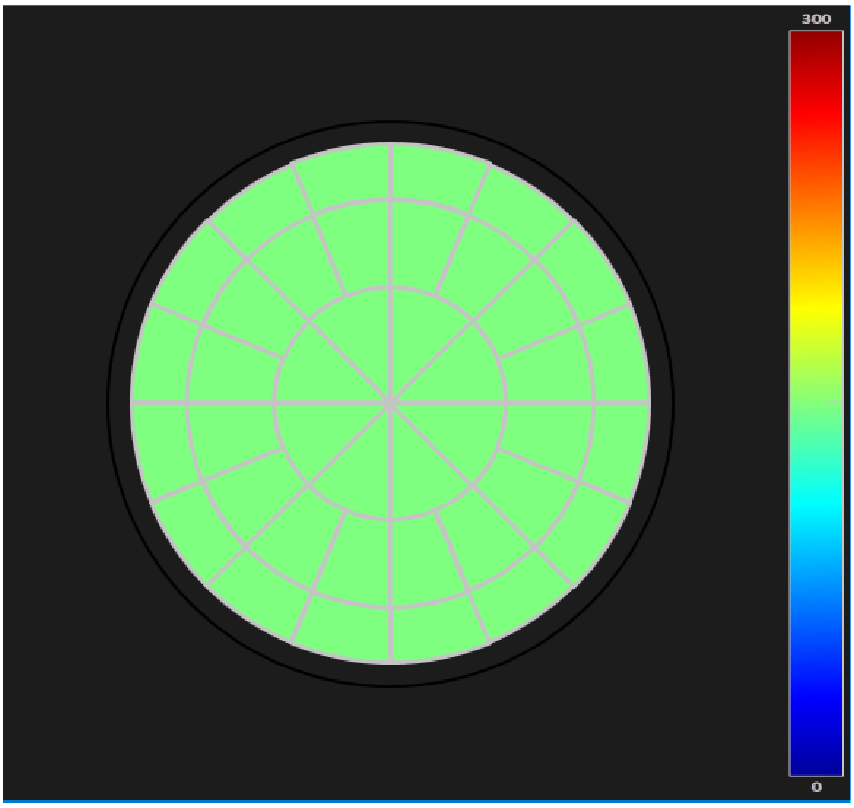
Click **Default** to apply default settings:

- Color Table = Jet
- Show ID Overlay = disabled
- Zernike Pattern Orientation: Flip = horizontal, Rotate = none
- Control Step Delay = 10 ms

Click **OK** to apply changes or **Cancel** to discard them.

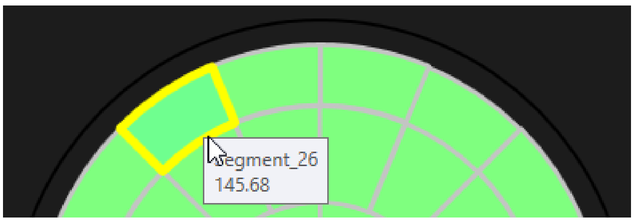
## 4.6.5 Display Mirror Control

The default start screen of the Thorlabs Deformable Mirror software shows the mirror segments and the voltages applied to the segments.




The color of the mirror segments represents the applied voltage according to the color scheme displayed in the color bar to the right. The color scheme can be changed in the Settings 22 menu.

Hovering the mouse over a mirror segment causes a window to appear where the segment number and the applied voltage are displayed:

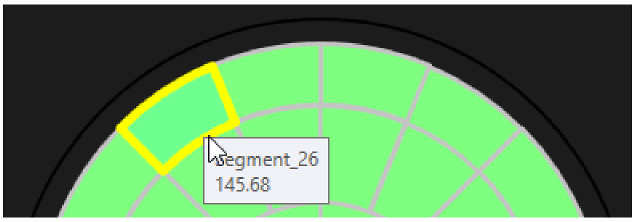


#### 4.6.5.1 Individual Segment Control

**Single Segment Control**

The individual segment voltages can be changed:

1. Move the mouse over the segment. When the segment voltage is displayed, turn the mouse wheel. The segment color changes in accordance with the voltage:




2. Hover the mouse over the segment, then click right mouse button. A dialog opens.


Shifting the slider results in a coarse voltage change (see displayed numeric value and segment color). Alternatively, you can input the desired voltage numerically. Finally, using the mouse scroll wheel (or cursor buttons), the segment voltage can be changed with the following increments:

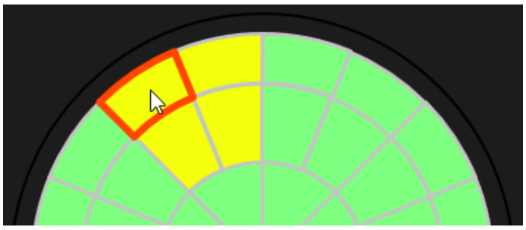
| | | | Increment |
|---|---|---|---|
| Ctrl + | Mouse Wheel | (←↑↓→) | 0.2 V |
| | Mouse Wheel | (←↑↓→) | 1.0 V |
| Shift+ | Mouse Wheel | (←↑↓→) | 10.0 V |

**Note**

"Restore (Ctrl+A)" resets the voltage of all segments to 150 V. Additionally, all Zernike sliders are set to zero.

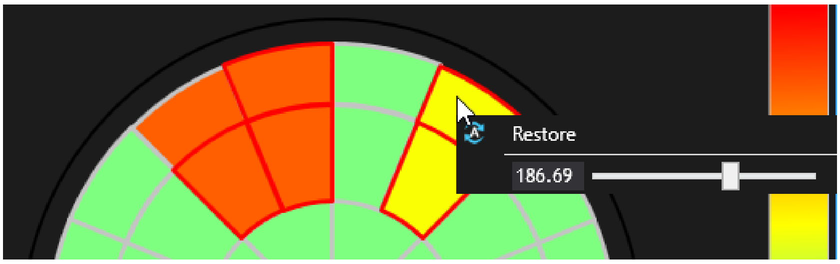
#### 4.6.5.2 Control in Arbitrary Groups of Segments

Left click on a segment to select it. Selected parts appear with a red rim. Place the mouse pointer over a selected segment and turn the mouse wheel. The voltages of all selected elements will change with the same increment:



**Notes**

- If the elements were set previously to a selection of different voltages, the change will apply as an offset to all segments:




- By right clicking on a selected element, the slider in the pop-up window allows you to change only the individual segment voltage.
- Press the button to cancel selection of segments.

### 4.6.6 Control Panel

The control panel on the left side is designed in an "outlook bar" style, where only the active tab is expanded and highlighted. Three panels are available:

- Zernike Control 25
- Mirror Manipulation 27
- Control Loop Settings 28 this pannel is only active when a Control Loop is used.

Click to the desired panel header to expand it.

#### 4.6.6.1 Zernike Control

The **Zernike** manipulation panel allows a predefined voltage pattern to be applied on all segments in order to introduce deterministic distortions to the reflected wavefront or to compensate for distortions of the incident wavefront.


The button (Zernike Home) **resets all** Zernike sliders to their home position. Double click the Zernike name (e.g. "Z5 Def") to **reset the appropriate** Zernike to its home position.

**Note**

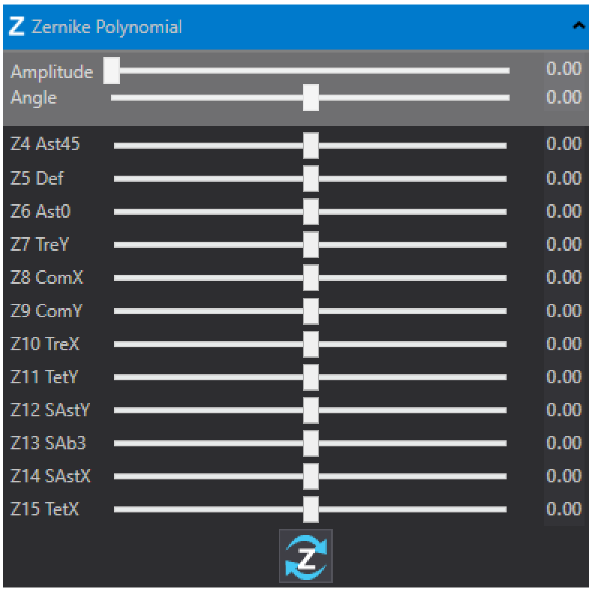
Resetting Zernike sliders to home position means that the appropriate Zernike coefficients are set to zero. The voltage pattern on the mirror segments is generated accordingly.

Any segment voltages that were generated by direct mirror segment manipulation 27, will remain unchanged after homing Zernikes.

**Note**

Amplitude and Angle refer to the tilting function in the DMP40 which is not available for the DMH40 due to absence of tilt arms. It is therefore grayed out.

#### 4.6.6.1.1 Zernike Control of Higher Order




The sliders for Amplitude and Angle are grayed out for the DMH40 because the DMH40 does not have tilting arms like the DMP40.

The sliders for control of Zernike Z4 to Z15 allow a predefined segment voltage pattern to be set up that introduces a wavefront distortion described by the selected Zernike coefficient. The sliders allow you to change Zernikes within a control range that is limited by the stroke of individual segments. Due to the dependency on the optical setup, materials used in the beam propagation path, and specific piezoelectric effects, the control range cannot be calibrated in absolute values.

Control sliders and numerical inputs allow each Zernike to be set within a relative range between -1 and +1.

In the closed loop control mode, the sliders show the correction of the mirror surface that is necessary to maintain a given wavefront.

Shifting the slider results in a coarse Zernike change. Alternatively, you can input the desired value numerically. Finally, using the mouse scroll wheel (or cursor buttons), the slider value can be changed with the following increments:

| | | | Increment |
|---|---|---|---|
| Ctrl + | Mouse Wheel | (←↑↓→) | 0.01 |
| | Mouse Wheel | (←↑↓→) | 0.05 |
| Shift+ | Mouse Wheel | (←↑↓→) | 0.1 |

Double click the Zernike name (e.g. "Z5 Def") to ***reset the appropriate*** Zernike to its home position.

Press the (Zernike Home) button to ***reset all*** Zernike sliders, including the Amplitude and Angle sliders, to their home position.

**Note**

Resetting Zernike sliders to home position means that the appropriate Zernike coefficients are set to zero. The voltage pattern on the mirror segments is generated accordingly.

Any segment voltages that were generated by direct mirror segment manipulation 27, will remain unchanged after homing Zernikes.

### 4.6.6.2 Mirror Manipulation

In the tab **Mirror Manipulation**, segment rings and/or sectors (eighths of the mirror surface) can be selected to be manipulated simultaneously.


**Ring Selection**

| No. | Ring | Segments |
|---|---|---|
| 1 | inner | 1 to 8 |
| 2 | middle | 9 to 24 |
| 3 | outer | 25 to 40 |

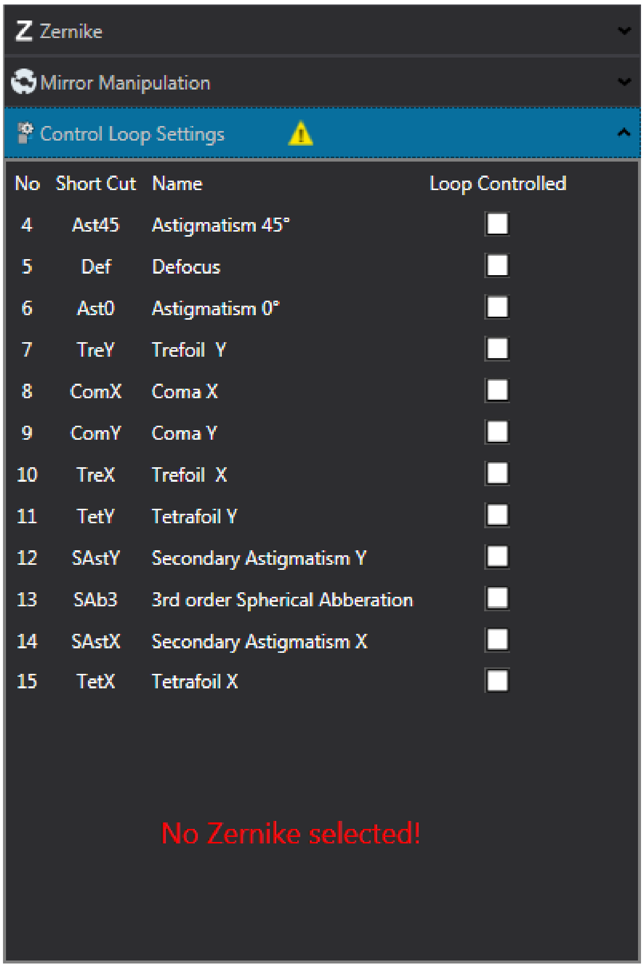
**Eighths Selection**

| No. | Segments |
|---|---|
| 4 | 1, 9, 10, 25, 26 |
| 5 | 2, 11,12, 27, 28 |
| 6 | 3, 13, 14, 29, 30 |
| 7 | 4, 15, 16, 31, 32 |
| 8 | 5, 17, 18, 33, 34 |
| 9 | 6, 19, 20, 35, 36 |
| 10 | 7, 21, 22, 37, 38 |
| 11 | 8, 23, 24, 39, 40 |

The made selection can be canceled by either pressing the same icon again, or via the toolbar icon 21 'Cancel Segment Selection' ( ).

### 4.6.6.3 Control Loop Settings

In the Control Loop Settings menu, the user can select Zernikes to maintain at 0.

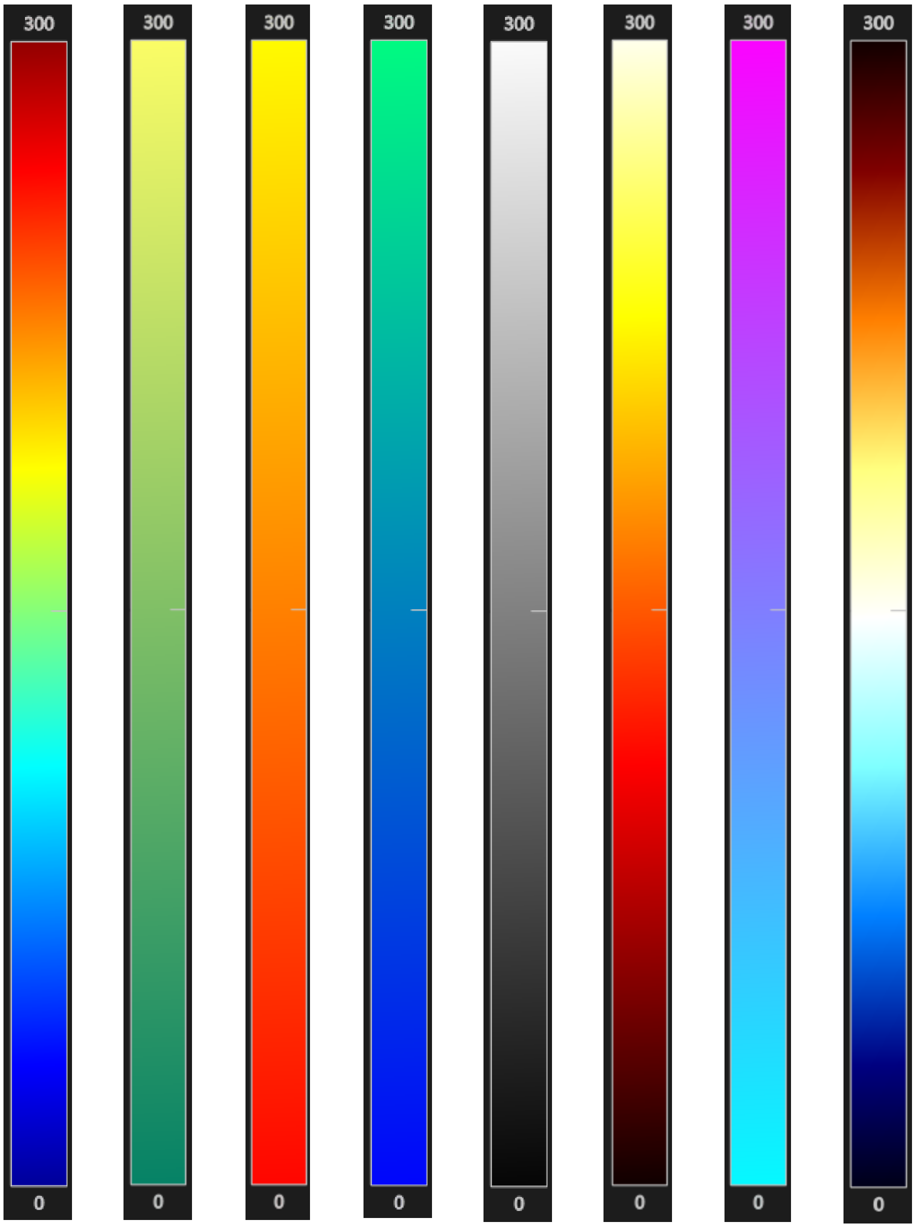



Selected Zernikes are indicated by a check mark.

If no Zernikes are selected, a warning icon will be displayed in the header bar and the menu topic CONTROL LOOP 20 is colored in red. The Control Loop menu from the menu bar offers the same settings in short form:

### 4.6.7 Color Bar

The color bar represents the voltage that is applied to a segment, in a certain color. There are several color tables available that can be selected in the Settings 22 menu.




Jet (default) | Summer | Autumn | Winter | Grey | Hot | Cool | Jet White

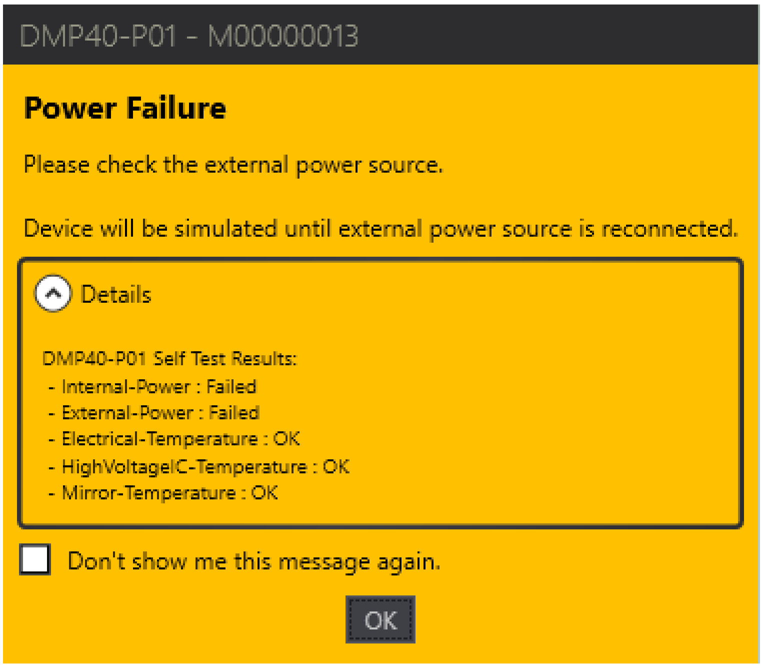
### 4.6.8 Status Bar


The status bar displays (from left to the right):

- status and duration of control loop;
- number of Zernikes that is used for closed loop control 28;
- instrument status
- current date and time

If an error was detected, the message 

appears and a separate window pops up that describes the detected error in detail, e.g.:

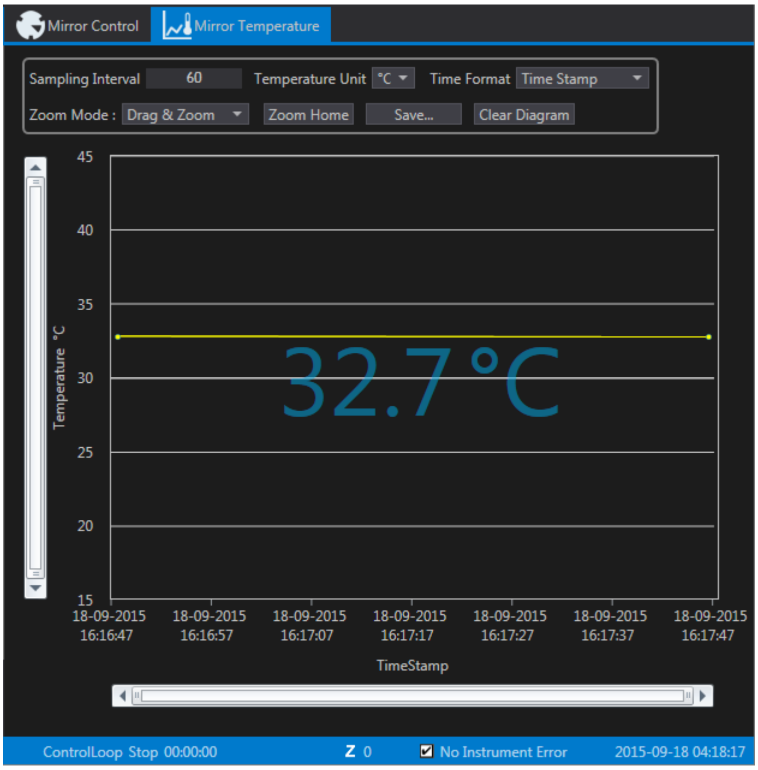



By checking the button "Don't show me this message again", you can omit further display of error messages.

Please see section Troubleshooting 43 for detailed description of possible error messages.

## 4.6.9 Display Mirror Temperature

The mirror temperature chart is displayed in a separate tab next to the mirror control display:



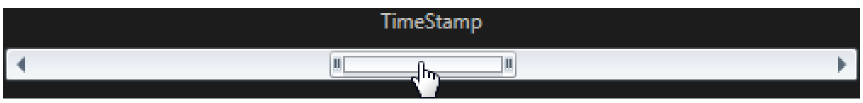

The temperature at the rear side of the mirror is recorded and starts automatically with application start.

| **Parameters** | **Selection** | **Factory Default** |
|---|---|---|
| Sampling Interval | 1 to 3600 sec | 60 sec |
| Temperature Unit | °C, °F, K | °C |
| Time Format | Time Stamp (date and time)<br>Elapsed time (hh:mm:ss) | Time Stamp |
| Zoom Mode | Drag & Zoom; Panning<br>Panning only | Drag and Zoom |
| Save | Save as *.csv<br>Save as image (JPG, PNG, BMP) | - |

### Panning

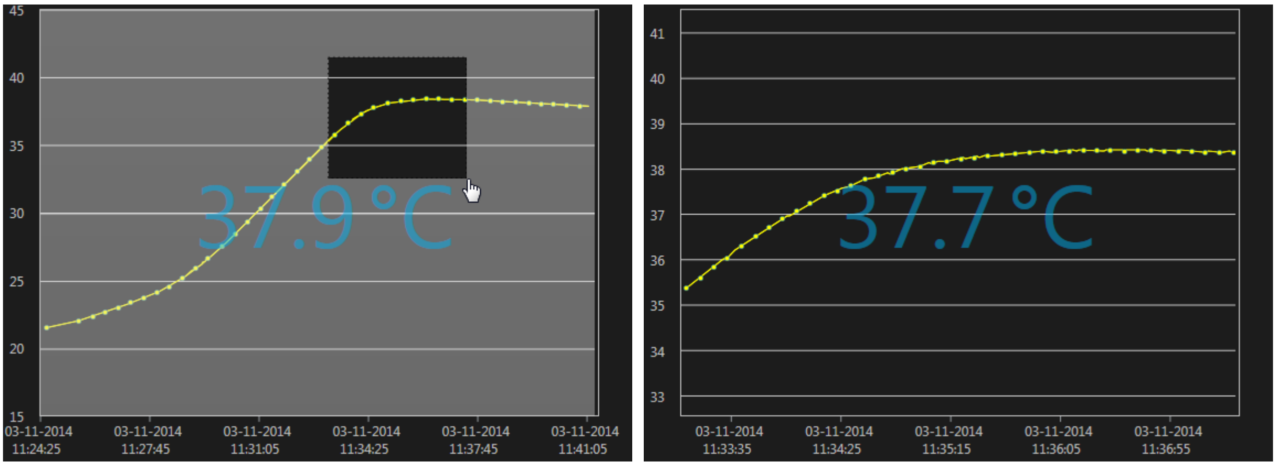
Move the mouse cursor over the time or temperature bar, until the cursor changes to ⇔:

Click and move the mouse until you get the desired zoom factor. If necessary, repeat for the other end of the bar. Then release the mouse and move its cursor over the bar so that it changes to 👆. Click and hold to pan the diagram:



**Drag & Zoom**

Press and hold the left mouse button, the draw an rectangle around the area of interest. By releasing the mouse button, the display zooms in the marked area.




Press **Zoom Home** to reset the diagram - all recorded values are restored.

Press **Save** to save the accumulated temperature values to either a *.CSV file or an image. Saving as an image is possible in BMP, JPG or as a transparent PNG.

Press **Clear Diagram** to delete the temperature record and restart the temperature logging.

All settings made to the Thorlabs Deformable Mirror software are saved when terminating the program, and are restored with the next software session.

### 4.6.10 The Configuration File

The configuration file comprises of three main parts:

- General information: Information about software version, driver version and the recognized instrument
- Application settings
  - Size and position of the GUI
  - Active Control Panel 25
  - Color Style 29
  - ID Overlay Status 21
  - Zernike Pattern Orientation 22
  - Control Loop Settings 20 (delay, selected Zernikes)
- Data
  - Status of hysteresis compensation
  - Voltage pattern that is applied to mirror segments
  - Zernike amplitudes (for information only)
  - Zernike slider positions

At the first start of the Thorlabs Deformable Mirror software, a default configuration is loaded. The table below shows the details of this configuration:

**Default Configuration**

| Parameter | Value |
|---|---|
| **Application Settings** | |
| GUI Window Position | X=0; Y=0 (left upper corner of the display) |
| GUI Window Size | width = 1024, height = 730 |
| Active Control Panel | Zernike |
| Color Table Type | Jet |
| ID Overlay (Segment Numbering) | hidden |
| Manual Setting of Zernike Orientation | Flip = horizontal<br>Rotate = none |
| Control Loop Settings | DataSocket address: dstp://localhost/WFS_WavefrontSensor<br>Control step delay = 10 ms<br>Selected for control loop Zernikes: none |
| Info Dialogs | Enabled. Error messages will be displayed. |
| **Application Settings** | |
| Status of Hysteresis Compensation | enabled |
| Voltages on Inner Mirror Segments | 150 V |
| Zernike Sliders | 0 |

This default configuration can be restored at any time by clicking to the Reset Application Settings  button in the tool bar.

When closing the application, all settings and data will be saved automatically. These most recent settings are being loaded when starting the application again so that the last configuration will be restored.

## 4.7 Closed Loop Control

To flatten a beam wavefront, Thorlabs deformable mirrors can be run with a feedback control via a signal from a wavefront sensor. Such a setup, involving light being directed to both the wavefront sensor and the deformable mirror with feedback from the wavefront sensor through the Thorlabs Deformable Mirror software is described in the operation manual for the DMP40. Please be aware that the pupil diameter of the DMH40 is larger than the diamter of the DMH40: 14 mm versus 10 mm respectively. Therefore, we recommend to use either the Thorlabs Wavefront Sensors WFS30 or WFS40, as they have a larger aperture as well, or to apply appropriate corrective optics. Please contact Thorlabs in case of questions.

# 5 Write Your Own Application

In order to write your own application, you need a specific instrument driver and some tools for use in different programming environments. The driver and tools are included in the installer package.

In this section the location of drivers and files, required for programming in different environments, are given for installation under Windows® 7 (32 and 64 bit)

**Note**

Thorlabs Deformable Mirror software and drivers contains 32 bit and 64 bit applications.

In 32 bit systems, only the 32 bit components are installed to

**`C:\Program Files\...`**

In 64 bit systems the 64 bit components are being installed to

**`C:\Program Files\...`**

while 32 bit components can be found at

**`C:\Program Files (x86)\...`**

In the table below you will find a summary of what files you need for particular programming environments.

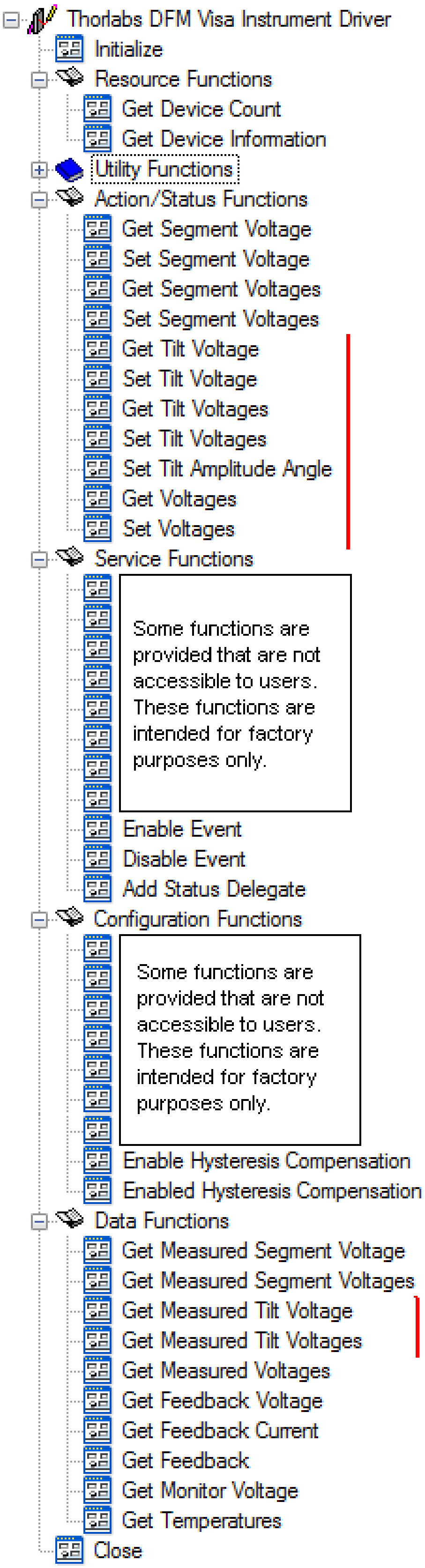
| Programming environment | Necessary files |
|---|---|
| **C, C++, CVI** | *.fp (function panel file; required for CVI IDE only)<br>*.h (header file)<br>*.lib (static library)<br>*.dll (dynamic linked library) |
| **C#** | .net wrapper dll |
| **LabView™** | *.fp (function panel)<br>Beside that, LabVIEW™ driver vi's are provided with the *.llb container file |

In the next sections the location of above files is described in detail.

**Note**

Two drivers are provided for the DMH40:

**TLDFM** driver - This is the basic driver for direct communication with the DMH40. An overview is given below:




**Comments**

Find connected hardware
Retrieve device information

Set / Get voltage of single segment

Set / Get voltage arrays to/from multiple segments

Functions to manipulate tilt arms and Get/Set Voltages are only available for the DMP40. The DMH40 does not have tilt arms.

Set / Get voltages to all arms and segments

Only 3 of the Service Functions are accessible by default. Hidden functions are not relevant for the user, because they are dedicated to manufacturing purposes only.

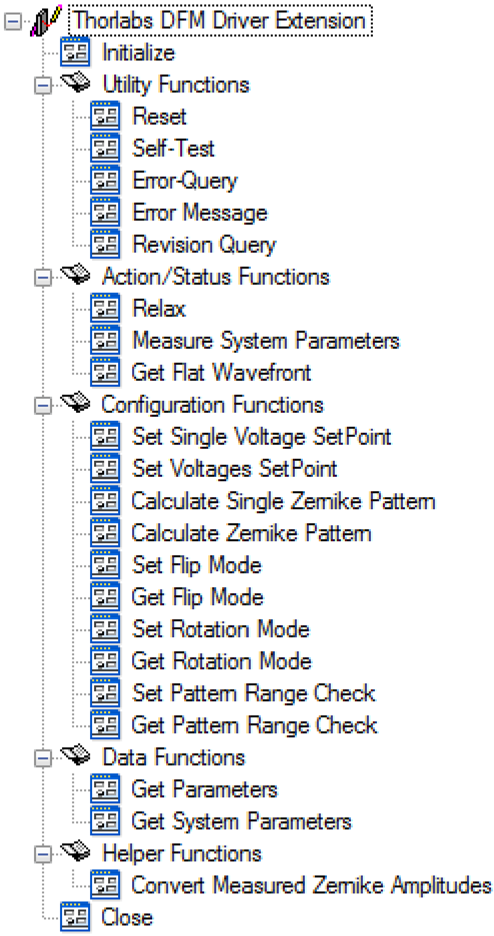
There are only two configuration functions accessible to users: 1) enable hysteresis compensation; 2) get status of hysteresis compensation

Data functions allow voltages of single segments or arrays of segments, as well as the mirror temperatures, to be retrieved. Functions to manipulate tilt arms are only available for the DMP40.

"Feedback" functions are for future use.

**TLDFMX** driver - This is the driver extension that provides a calculation library to the programmer. For example, calling the "Calculate Zernike Pattern" function and handing over the desired amplitudes, the driver extension returns the pattern in an array of segment voltages. This returned pattern is then passed to an appropriate basic driver function in order to set this calculated voltage pattern to the DMH40. An overview is given below:




**Comments**

Utility functions
Used for common tasks

Action/Status functions
Used for complex operations

Configuration functions are different from configuration functions in the basic driver!

Data functions allow the following to be retrieved:
- the parameters of the extension driver
- measured parameters of the control loop

Convert Zernike results from wavefront sensor into DMH40 representation

## 5.1 Instrument driver 32bit on 32bit systems

```
C:\Program Files\IVI Foundation\VISA\WinNT\Bin\TLDFM_32.dll
C:\Program Files\IVI Foundation\VISA\WinNT\Bin\TLDFMX_32.dll
```

**Note**

This instrument driver is required for all development environments!

**NI LabVIEW™ driver (including an example VI)**
```
C:\Program Files\National Instruments\LabVIEW xxxx\Instr.lib\...
...TLDFM\TLDFM.llb
...TLDFMX\TLDFMX.llb
```
(LabVIEW™ container file with driver vi's - "LabVIEW™ xxxx" stands for actual LabVIEW™ installation folder.)

**Header file**
```
C:\Program Files\IVI Foundation\VISA\WinNT\include\TLDFM.h
C:\Program Files\IVI Foundation\VISA\WinNT\include\TLDFM_def.h
C:\Program Files\IVI Foundation\VISA\WinNT\include\TLDFMX.h
C:\Program Files\IVI Foundation\VISA\WinNT\include\TLDFMX_def.h
```

**Static Library**
```
C:\Program Files\IVI Foundation\VISA\WinNT\lib\msc\TLDFM_32.lib
C:\Program Files\IVI Foundation\VISA\WinNT\lib\msc\TLDFMX_32.lib
```

**Function Panel**
```
C:\Program Files\IVI Foundation\VISA\WinNT\TLDFM\TLDFM.fp
C:\Program Files\IVI Foundation\VISA\WinNT\TLDFMX\TLDFMX.fp
```

**.net wrapper dll**
```
C:\Program Files\Microsoft.NET\Primary Interop Assemblies\...
...Thorlabs.TLDFM_32.interop.dll
...Thorlabs.TLDFMX_32.interop.dll
```

**Example for C**

`C:\Program Files\IVI Foundation\VISA\WinNT\TLDFM\Examples\Csample`

`sample.c` - C program how to communicate with a DMH40

`...\bin\TLDFM_Sample_x86.exe` - same, but executable

`C:\Program Files\IVI Foundation\VISA\WinNT\TLDFMX\Examples\Csample`

`sample.c` - C program how to use the extended driver functions

`...\bin\TLDFMX_Sample_x86.exe` - same, but executable

**Example for C#**

Project file
```
C:\Program Files\IVI Foundation\VISA\WinNT\TLDFM\...
...Examples\DotNet\Sample.csproj-
C:\Program Files\IVI Foundation\VISA\WinNT\TLDFMX\...
...Examples\DotNet\Thorlabs.TLDFMX_32.Interop.Sample.csproj-
```

**Example for LabView™**

Included in driver llb container

## 5.2 Instrument driver 32bit on 64bit systems

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\Bin\TLDFM_32.dll
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\Bin\TLDFMX_32.dll
```

**Note**

This instrument driver is required for all development environments!

**NI LabVIEW™ driver (including an example VI)**

```
C:\Program Files (x86)\National Instruments\LabVIEW xxxx\...
...Instr.lib\TLDFM\TLDFM.llb
...Instr.lib\TLDFMX\TLDFMX.llb
```

(LabVIEW™ container file with driver vi's - "LabVIEW xxxx" stands for actual LabVIEW™ installation folder.)

**Header file**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include\TLDFM.h
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include...
...\TLDFM_def.h
```

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include\TLDFMX.h
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include...
...\TLDFMX_def.h
```

**Static Library**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\lib\msc...
...\TLDFM_32.lib
```

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\lib\msc...
...\TLDFMX_32.lib
```

**Function Panel**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFM\TLDFM.fp
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFMX\TLDFMX.fp
```

**.net wrapper dll**

```
C:\Program Files (x86)\Microsoft.NET\Primary Interop Assemblies...
...\Thorlabs.TLDFM_32.interop.dll
...\Thorlabs.TLDFMX_32.interop.dll
```

**Example for C**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFM\...
...Examples\CSample
```

`sample.c` - C program how to communicate with a DMH40
`...\bin\TLDFM_Sample_x86.exe` - same, but executable

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFMX\...
...Examples\CSample
```

`sample.c` - C program how to use the extended driver functions
`...\bin\TLDFMX_C_Sample_x86.exe` - same, but executable

**Example for C#**
Project file
```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFM\...
...Examples\DotNet\Sample.csproj
```

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\TLDFMX\...
...Examples\DotNet\Thorlabs.TLDFMX_32.Interop.Sample.csproj
```

**Example for LabVIEW™**
Included in driver llb container

## 5.3 Instrument driver 64bit on 64bit systems

```
C:\Program Files\IVI Foundation\VISA\Win64\Bin\TLDFM_64.dll
C:\Program Files\IVI Foundation\VISA\Win64\Bin\TLDFMX_64.dll
```

**Note**

This instrument driver is required for all development environments!

**NI LabVIEW™ driver (including an example VI)**

```
C:\Program Files\National Instruments\LabVIEW xxxx\...
...Instr.lib\TLDFM\TLDFM.llb
...Instr.lib\TLDFMX\TLDFMX.llb
```

(LabVIEW™ container file with driver vi's - "LabVIEW xxxx" stands for actual LabVIEW™ installation folder.)

**Header file**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include\TLDFM.h
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include...
...\TLDFM_def.h

C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include\TLDFMX.h
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\include...
...\TLDFMX_def.h
```

**Static Library**

```
C:\Program Files\IVI Foundation\VISA\Win64\Lib_x64\...
...msc\TLDFM_64.lib
...msc\TLDFMX_64.lib
```

**Function Panel**

```
C:\Program Files (x86)\IVI Foundation\VISA\WinNT\...
...TLDFM\TLDFM.fp
...TLDFMX\TLDFMX.fp
```

**.net wrapper dll**

```
C:\Program Files (x86)\Microsoft.NET\Primary Interop Assemblies...
...\Thorlabs.TLDFM_32.interop.dll
...\Thorlabs.TLDFMX_32.interop.dll
```

**Example for C**

Source code file is the same as 32bit on 64bit systems 38.

**Example for C#**

Project file (same as 32bit on 64bit systems 39)

**Example for LabVIEW™**

Included in driver llb container.

# 6 Maintenance and Service

Protect the DMH40 from adverse weather conditions. The DMH40 is not water resistant.

**Attention**

**To avoid damage to the instrument, do not expose it to spray, liquids or solvents!**

The unit does not need regular maintenance by the user. It does not contain any modules and/or components that could be repaired by the user himself.

Do not open the housing!

Since the optical mirror of the DMH40 is very thin and mounted on a flexible surface, it is extremely vulnerable!

**Attention**

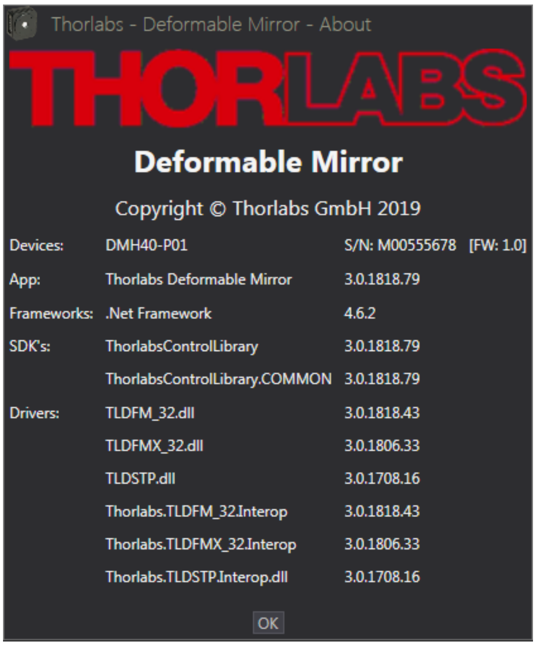
The DMH40 must not be cleaned from dust using ethanol, cleaning tissue, cotton tipped applicators or any other mechanical tools! Using these chemical and / or mechanical tools voids warranty!

Remove dust using only oil- and water-free compressed gas, such as Thorlabs Duster CA4-US or CA4-EU (Tetrafluoroetane). Keep the gas nozzle at least at a distance of 4 inches (10 cm) from the mirror surface, otherwise liquid gas drops may hit the surface and leave visible traces on the mirror surface; moreover the air pressure might damage the mirror.

In case of malfunction of the DMH40, please contact Thorlabs 58 for return instructions 53.

## 6.1 Version Information

Select the icon from the **HELP** menu or in the toolbar for detailed information about the software and the recognized DMH40:



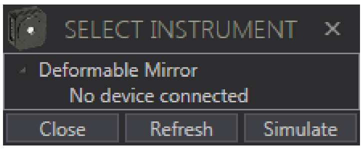

The keyboard button **F1** brings up the online help - either the entire help document or context sensitive.

**Note**

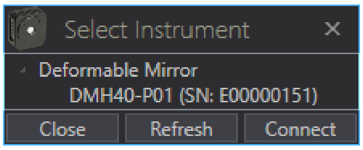
Context sensitive help means that the online help opens at the point that describes the selected functionality. **Example**: A Zernike slider was moved. Pressing F1 brings up the section Zernike Control of the help file.

## 6.2 Troubleshooting

- **When starting the Thorlabs Deformable Mirror software, a SELECT INSTRUMENT error message appears:**

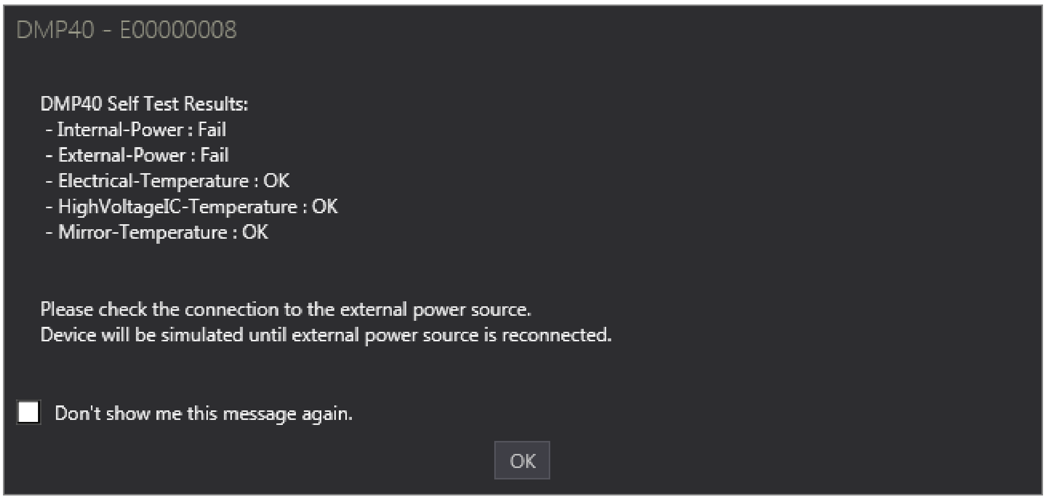



  - A DMH40 was not recognized to be connected to the PC.
  - Click Refresh to find a connected deformable mirror. If unsuccessful:
  - Verify your USB connection to the DMH40, and make sure that it is also connected to the supplied AC power adapter. Then click refresh. If a DMH40 is recognized now, its type and serial number will be displayed - then click the connect button.



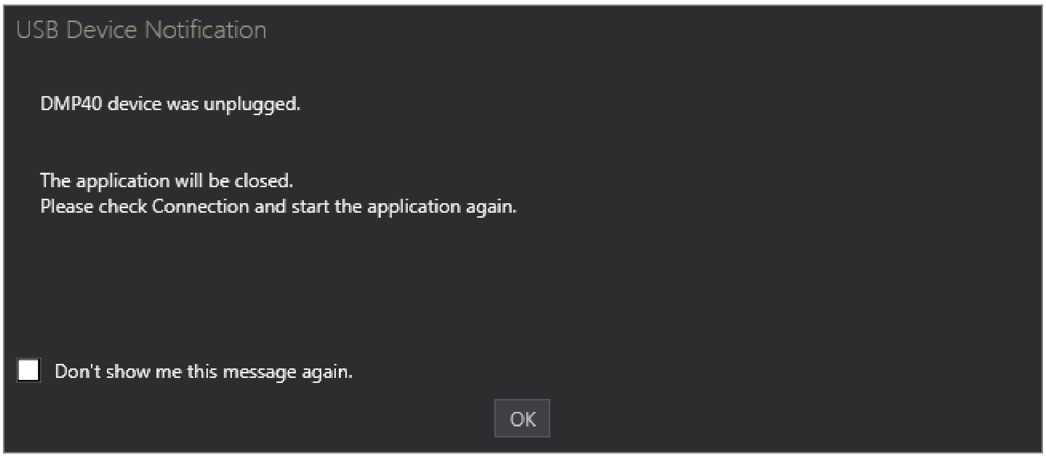

  - Alternatively, you can select **Simulate** - the Thorlabs Deformable Mirror software will open in simulation mode, the header will appear accordingly:


- **When starting the Thorlabs Deformable Mirror software, a DMH40 Self Test Results message appears:**



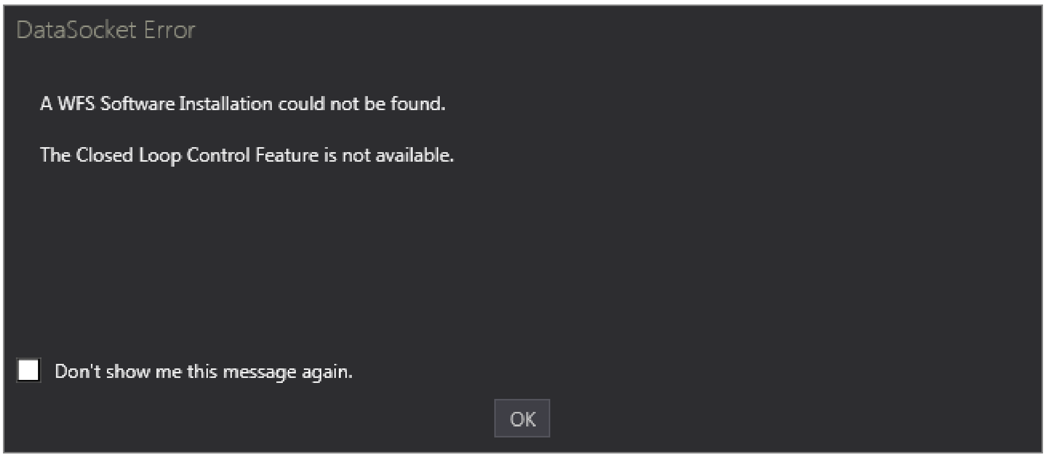

  - A DMH40 was recognized, but its DC power supply is missing (not connected or power failure). The DMH40 status LED lights up red.
  - If closing the error message, the GUI opens with disabled DMH40 control. Check the external DMH40 power supply and make sure, the status LED changes to a green light. Then the GUI will be operable as intended.
  - By checking the button "Don't show me this message again", you can omit further display of this error.

- **During the Thorlabs Deformable Mirror software operation, a USB DEVICE NOTIFICATION error message appears:**




- ➢ The USB connection to the DMH40 was lost.
- ➢ Close the dialog - the GUI will be terminated. Re-establish the connection to the DMH40, verify that the status LED lights up green and start the application again.
- ➢ By checking the button "Don't show me this message again", you can omit further display of this error.

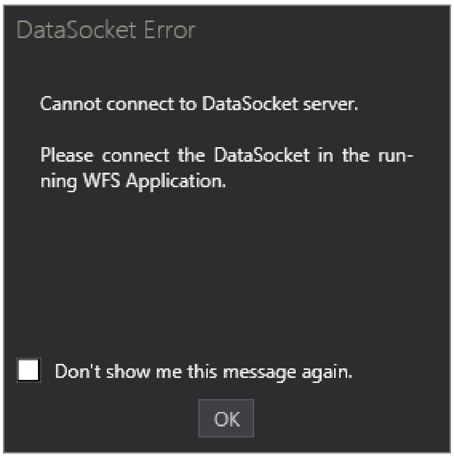
- **When starting the Thorlabs Deformable Mirror software, a DataSocket Error message appears:**




- ➢ No installation of the WFS software could be found on the computer.
- ➢ If you do not need the Closed Loop Control feature, just close the error message. The Thorlabs Deformable Mirror software starts and the Loop Control features will appear grayed out and disabled:


- ➢ If you need this feature, please install the WFS software that can be downloaded from the Thorlabs web site, and start the WFS software. If you have any difficulties in finding the software, please contact Thorlabs 58.
- ➢ By checking the button "Don't show me this message again", you can omit further display of this error.

- **When clicking to the DataSocket Connection icon ( ) an error message appears:**




➢ The DataSocket was not connected in the WFS software. Connect the DataSocket server.

➢ By checking the button "Don't show me this message again", you can omit further display of this error.

**Important Note**

Once you have checked the button "Don't show me this message again", the appropriate message will not be displayed anymore. Restore this option by resetting the application settings .

- **Loading old .dmfd configuration files:**

With updating the Thorlabs Deformable Mirror software from older versions, the file structure of the configuration files may have changed form .dmfd to .dmfc. The .dmfd files will not readily be recognized by the new software version.

➢ There is a simple way to load old .dmfd configuration files and to convert them to the newer.dmfc format. Please follow the below steps:

1. Open ‘File’-Menu
2. Click ‘Load’
3. Switch Dialogs File-Extension-Filter to ‘|All Files|*.*‘
4. Load ‘*.dfmd‘ File
5. Save Configuration as ‘*.dfmc’ File [optional]
   a. Open ‘File’-Menu
   b. Click ‘Save User Configuration'

# 7 Appendix

## 7.1 Technical Data

| **Mirror** | **DMH40(/M)-F01** | **DMH40(/M)-P01** |
|---|---|---|
| Design | Compact housing with high-voltage drivers; USB control interface | |
| Mirror Principle | Unimorph piezoelectric | |
| Mirror Diameter | Ø 18.0 mm | |
| Number of Segments | 40 in total<br>24 within the pupil, 16 - outside | |
| Mirror Segment Voltage Range | 0 to 300 V (default: +150 V for flat mirror) | |
| **Optical Specifications** | | |
| Optical Aperture | Ø 17.0 mm | |
| Pupil Diameter [1]) | Ø 14.0 mm | |
| Surface flatness | 200 nm, RMS (Defocus term actively flattened) | |
| Coating | UV-Enhanced Aluminum | Protected Silver |
| Average Reflectance | >89.0% Over 250 nm to 450 nm | >97.5% Over 450 nm to 2 µm<br>>96.0% Over 2 to 20 µm |
| Damage Threshold, CW | 1 W/cm (250 nm – 450 nm) | 4 W/cm (450 nm – 2 µm) |
| Damage Threshold, Pulsed Signals | 0.2 J/cm$^2$ (355 nm, 10 ns, 10 Hz, Ø0.38 mm) | 1 J/cm$^2$ (1064 nm, 10 ns, 10 Hz, Ø10 mm) |
| Hysteresis of Piezoceramic Material [3]) | 20 % Typical, 25 % Max | |
| **Physical Stroke** [2]) | | |
| Z5 Defocus | ± 17.6 µm | |
| Z4, Z6 Astigmatism | ± 18.4 µm | |
| Z8, Z9 Coma | ± 6.8 µm | |
| Z7, Z10 Trefoil | ± 6.5 µm | |
| Z11, Z15 Tetrafoil | ± 5.7 µm | |
| Z12, Z14 Secondary Astigmatism | ± 3.0 µm | |
| Z13 3rd order Spherical Abberation | ± 2.7 µm | |
| **Dynamical Specifications** | | |
| Pattern Update Rate | 4 kHz via USB 2.0 (All Voltages) | |
| Mirror Response Time | 0.5 ms (Full Stroke) | |

[1]) Max. useable beam diameter relates to Zernike pupil diameter

[2]) Max. Peak-to-Valley (PV) stroke at mirror surface related to 14 mm beam diameter. The Defocus range may have an asymmetry of 30% max.

**Note** Wavefront amplitudes reflected from the mirror are twice as high

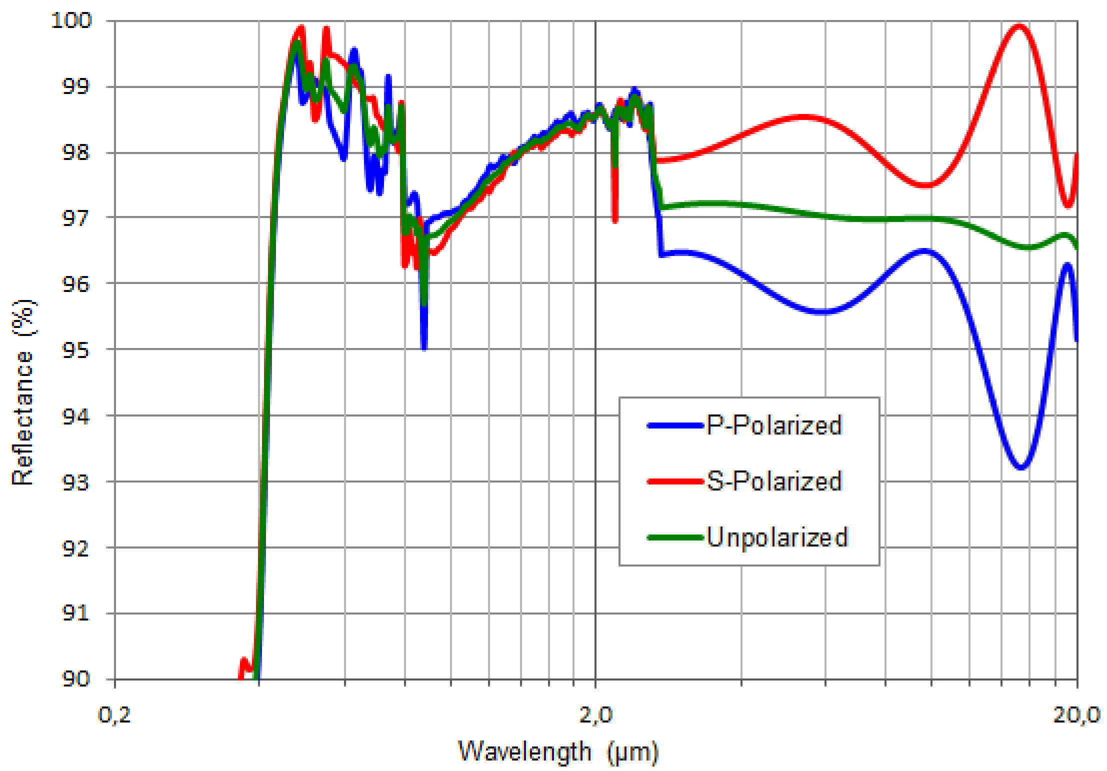
[3]) The control software for these mirrors includes built-in hysteresis compensation that greatly reduces the effect on mirror performance.

| Interface Connectors | |
|---|---|
| PC Control Interface | High Speed USB 2.0 (USB1.1 compatible)<br>Mini USB connector |
| Analog Feedback Input | Current: 1 nA to 10 mA<br>Voltage: 0 to +2.5 V<br>(2.5 mm stereo plug, max. 3 m cable, shielded) |
| **General Specifications** | |
| Operating Temperature Range [4]) | +5 to +35 °C |
| Storage Temperature Range | -20 to +70 °C |
| Power Supply | 12 V DC / 18 VA (desktop power supply, energy level VI) |
| Warm-up time | not required |
| Operating Altitude | max. 3000 m |
| Dimensions (W x H x D) | 64 x 60 x 31 mm (w/o dust cover) |
| Mounting Options | Thorlabs 30 mm cage system<br>SM2 front thread<br>UNC 8-32 and UNC 1/4-20 bottom thread<br>alternatively M4 and M6 thread (metric version) |
| Weight | 0.18 kg |

[4]) non-condensing

All technical data are valid at 23 ± 5°C and 45 ± 15% rel. humidity (non condensing)

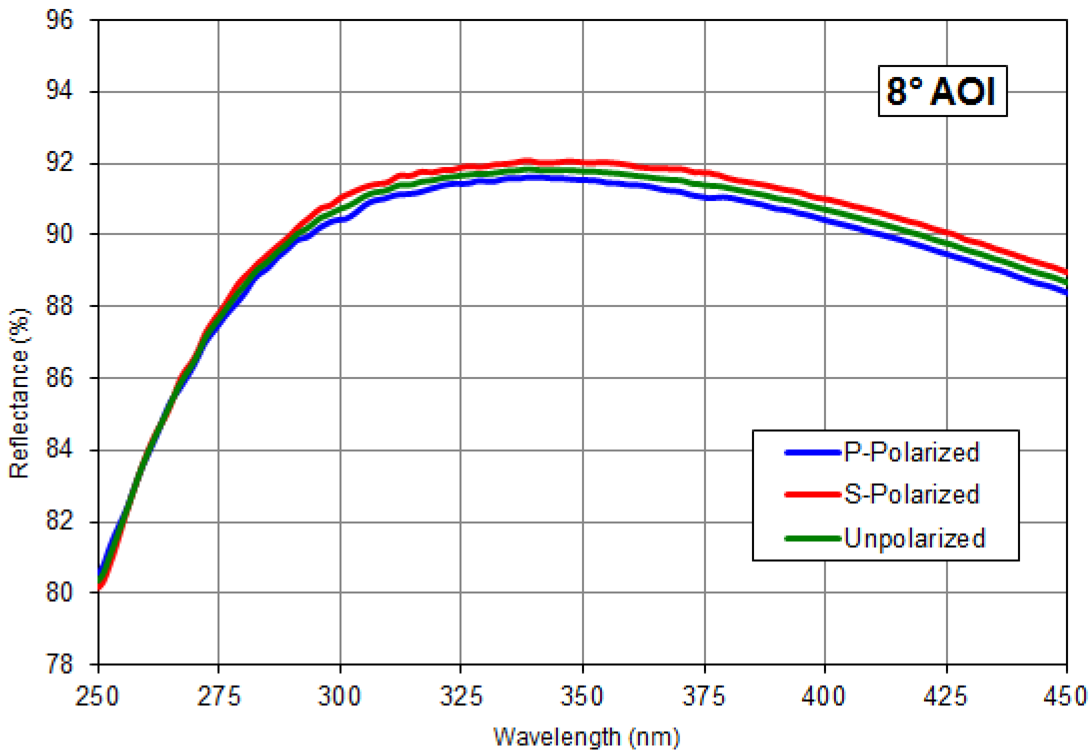
### Reflectance of the Protected Silver Coating

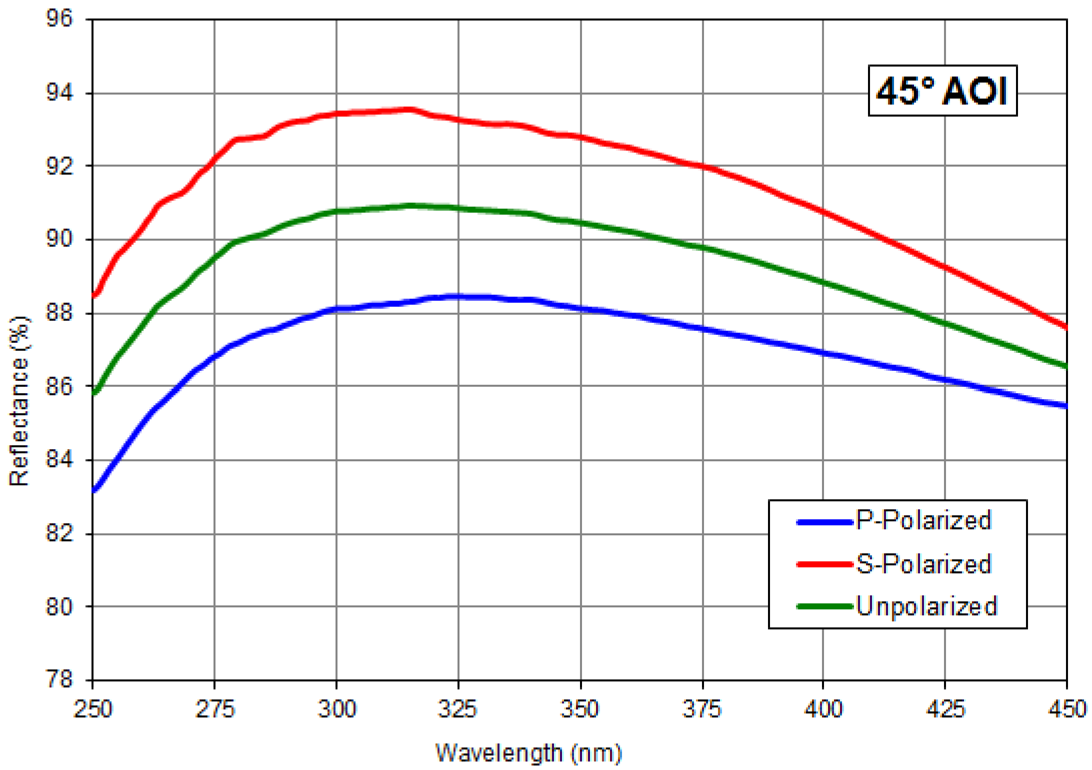


*Angle of Incidence 12°*

(Source:http://www.thorlabs.de/newgrouppage9.cfm?objectgroup_id=5056)

**Reflectance of the UV-Enhanced Aluminum Coating**



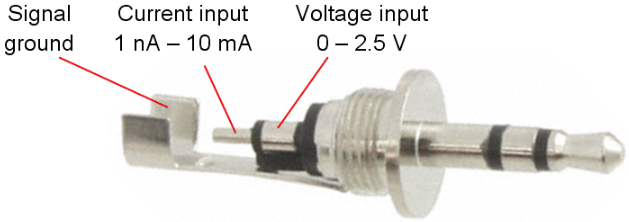

Compare: https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=264

**Note**

The DMH40-F01 provides an average reflectance of > 89% only.

## 7.2 Analog Feedback Connector

A analog feedback connector will help to establish a closed loop control using a photo detector as described in the chapter Closed Loop Control 33. The analog feedback connector is not enclosed in the shipment but may be purchased at any supplier.

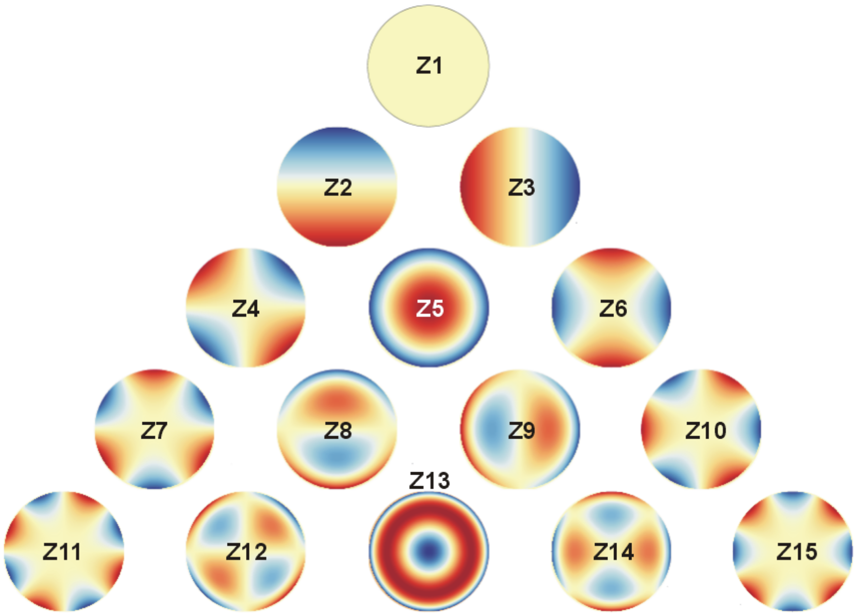



*Connection of the external feedback connector*
*(Stereo connector plug, Ø 2.5 mm)*

## 7.3 About Zernikes

A wavefront can be described using Zernike polynomials. These are a sequence of polynomials that are orthogonal on the unit circle. A variety of definitions exist for these Zernike functions. The Thorlabs Wavefront Sensor software and this manual follows the ANSI Standard Z80.28-210, see References [1] 56 .

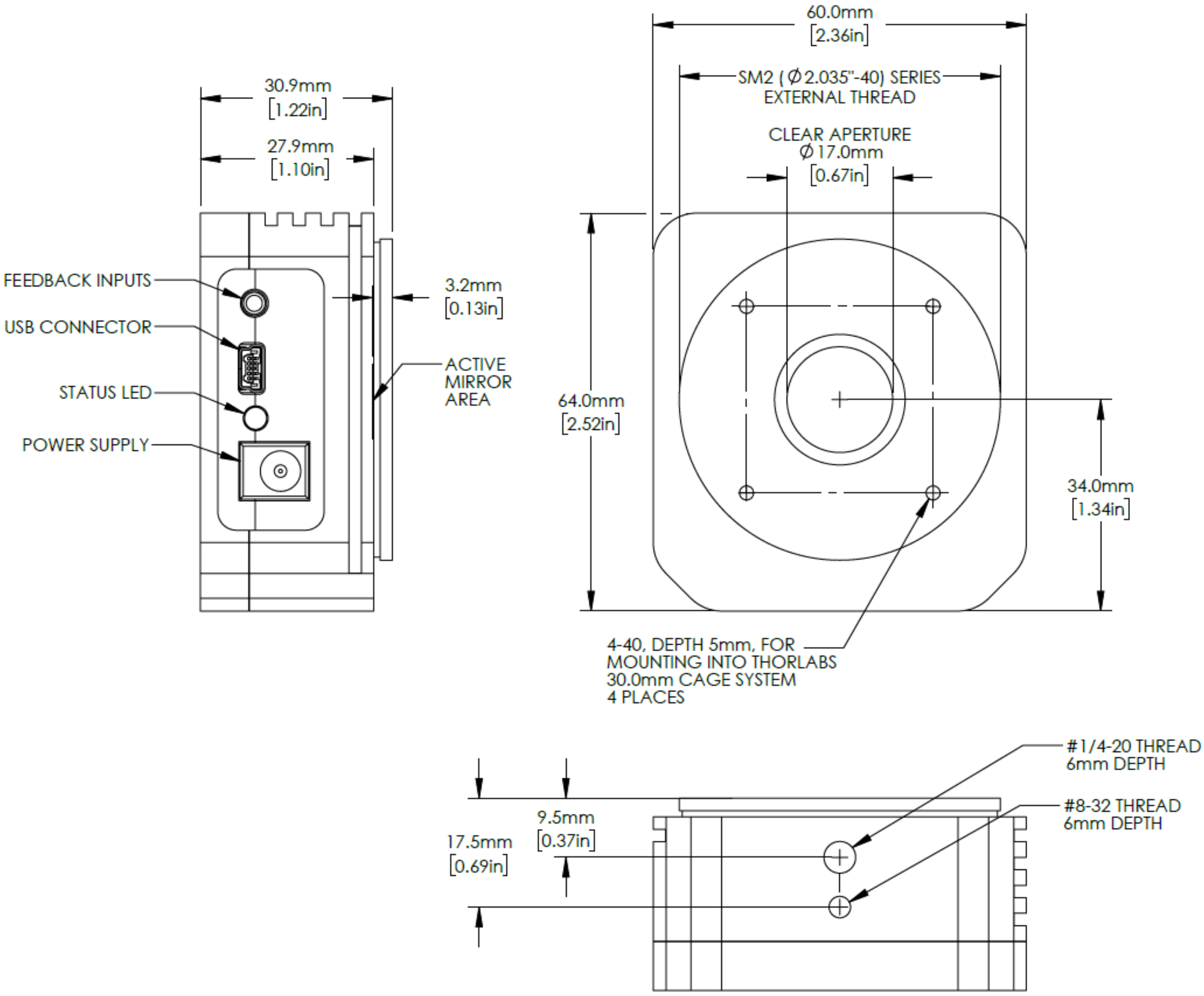
The graphic below illustrates the impact of Zernikes to the wavefront. Here, the Zernike index assignment is identical with the assignment used in Thorlabs Deformable Mirror software and WFS software:



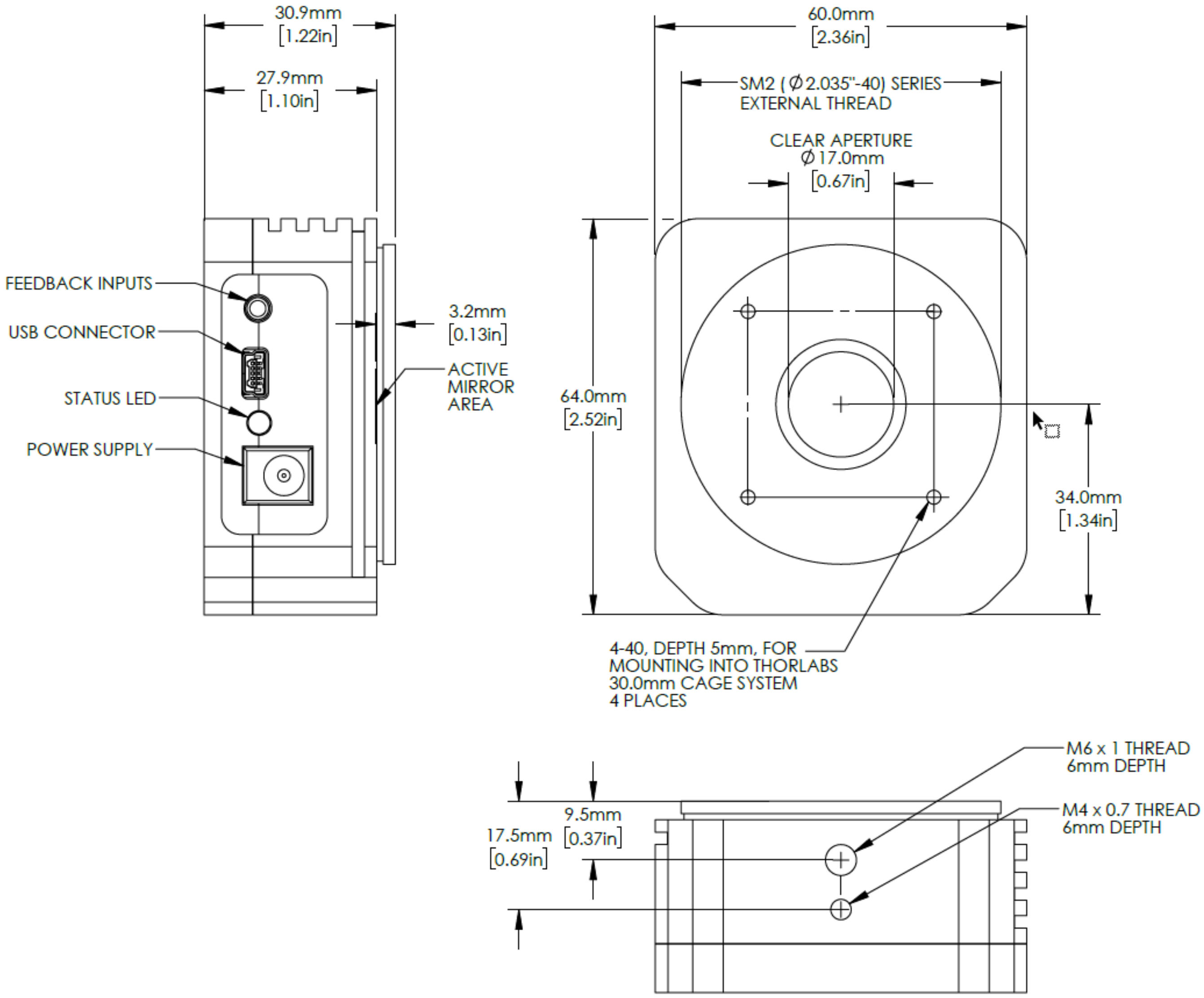



| Zernike Term | Shortcut | Description |
|---|---|---|
| Z 1 | - | Piston |
| Z 2 | - | Tip X |
| Z 3 | - | Tilt Y |
| Z4 | Ast45 | Astigmatism 45° |
| Z 5 | Def | Defocus |
| Z 6 | Ast0 | Astigmatism 0° |
| Z 7 | TreY | Trefoil Y |
| Z 8 | ComX | Coma X |
| Z 9 | ComY | Coma Y |
| Z 10 | TreX | Trefoil X |
| Z 11 | TetY | Tetrafoil Y |
| Z 12 | SAstY | Secondary Astigmatism Y |
| Z 13 | SAb3 | 3rd Order Spherical Abberation |
| Z 14 | SAstX | Secondary Astigmatism X |
| Z 15 | TetX | Tetrafoil X |

## 7.4 Dimensions DMH40-xxx (Imperial)



## 7.5 Dimensions DMH40/M-xxx (Metric)




## 7.6 Safety

**Attention**

**All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly as it was designed for.**

**Prior to applying power to the DMH40, make sure that the protective conductor of the 3 conductor mains power cord is correctly connected to the protective earth ground contact of the socket outlet! Improper grounding can cause electric shock with damages to your health or even death!**

**The DMH40 must not be operated in explosion endangered environments!**

**Do not open the cabinet, there are no parts serviceable by the operator inside!**

**Refer servicing to qualified personnel!**

**Only with written consent from *Thorlabs* may changes to single components be made or components not supplied by *Thorlabs* be used.**

**This precision device is only serviceable if properly packed into the complete original packaging. If necessary, ask for a replacement package prior to return.**

**Attention**

**Mobile telephones, cellular phones or other radio transmitters are not to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to IEC 61326-1.**

**This product has been tested and found to comply with the limits according to IEC 61326-1 for using connection cables shorter than 3 meters (9.8 feet).**

**Warning**

**The piezoelectric actuators are operated by a high DC voltage. Immediately disconnect the power supply if the mirror surface is damaged accidentally, do NOT touch any parts inside!**

## 7.7 Return of Devices

This precision device is only serviceable if returned and properly packed into the complete original packaging including the complete shipment plus the cardboard insert that holds the enclosed devices. If necessary, ask for replacement packaging. Refer servicing to qualified personnel.

## 7.8 Certifications and Compliances

# *EU Declaration of Conformity*

*in accordance with EN ISO 17050-1:2010*

*We:* Thorlabs GmbH

*Of:* Münchner Weg 1, 85232 Bergkirchen, Deutschland

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2014/35/EU | Low Voltage Directive (LVD) |
| 2014/30/EU | Electromagnetic Compatibility (EMC) Directive |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***DMP40(/M)-x, DMH40(/M)-x***

*Equipment:* ***Deformable Mirror-Series***

*is in conformity with the applicable requirements of the following documents:*

| | | |
|---|---|---|
| EN 61010-1 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use. | 2010 |
| EN 61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2013 |

*and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:*

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive

*I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.*

*Signed:* *On:* 07 November 2019

*Name:* Bruno Gross

*Position:* General Manager *EDC - DMP40(/M)-x, DMH40(/M)-x -2019-...*

## 7.9 Warranty

Thorlabs warrants material and production of the DMH40 for a period of 24 months starting with the date of shipment. During this warranty period Thorlabs will see to defaults by repair or by exchange if these are entitled to warranty.

For warranty repairs or service the unit must be sent back to Thorlabs. The customer will carry the shipping costs to Thorlabs, in case of warranty repairs Thorlabs will carry the shipping costs back to the customer.

If no warranty repair is applicable the customer also has to carry the costs for back shipment.

In case of shipment from outside EU duties, taxes etc. which should arise have to be carried by the customer.

Thorlabs warrants the hard- and/or software determined by Thorlabs for this unit to operate fault-free provided that they are handled according to our requirements. However, Thorlabs does not warrant a fault free and uninterrupted operation of the unit, of the software or firmware for special applications nor this instruction manual to be error free. Thorlabs is not liable for consequential damages.

**Restriction of Warranty**

The warranty mentioned before does not cover errors and defects being the result of improper treatment, software or interface not supplied by us, modification, misuse or operation outside the defined ambient stated by us or unauthorized maintenance.

Further claims will not be consented to and will not be acknowledged. Thorlabs does explicitly not warrant the usability or the economical use for certain cases of application.

Thorlabs reserves the right to change this instruction manual or the technical data of the described unit at any time.

## 7.10 Copyright and Exclusion of Liability

Thorlabs has taken every possible care in preparing this document. We however assume no liability for the content, completeness or quality of the information contained therein. The content of this document is regularly updated and adapted to reflect the current status of the hardware and/or software. We furthermore do not guarantee that this product will function without errors, even if the stated specifications are adhered to.

Under no circumstances can we guarantee that a particular objective can be achieved with the purchase of this product.

Insofar as permitted under statutory regulations, we assume no liability for direct damage, indirect damage or damages suffered by third parties resulting from the purchase of this product. In no event shall any liability exceed the purchase price of the product.

Please note that the content of this document is neither part of any previous or existing agreement, promise, representation or legal relationship, nor an alteration or amendment thereof. All obligations of Thorlabs result from the respective contract of sale, which also includes the complete and exclusively applicable warranty regulations. These contractual warranty regulations are neither extended nor limited by the information contained in this document. Should you require further information on this product, or encounter specific problems that are not discussed in sufficient detail in the document, please contact your local Thorlabs dealer or system installer.

## 7.11 References

[1] ANSI Z80.28-2010 Ophthalmics - Methods of Reporting Optical Aberrations of Eyes: ANSI eStandards.

## 7.12 Manufacturer Address

**Manufacturer Address Europe**
Thorlabs GmbH
Münchner Weg 1
D-85232 Bergkirchen
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Fax: +49-8131-5956-99
www.thorlabs.de
Email: europe@thorlabs.com

**EU-Importer Address**
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Fax: +49-8131-5956-99
www.thorlabs.de
Email: europe@thorlabs.com

## 7.13 Thorlabs Worldwide Contacts and WEEE policy

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

**USA, Canada, and South America**
Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

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**Japan**
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**UK and Ireland**
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techsupport.uk@thorlabs.com

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**China**
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chinasales@thorlabs.com

### Thorlabs 'End of Life' Policy (WEEE)

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return “end of life” Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out “wheelie bin” logo (see right), were sold to and are currently owned by a company or institute within the EC, and are not dissembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. “End of life” units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

# Index



 


UNLEASHED
Ezra