Delta 7 User Manual

Version 0.2.6- DRAFT

March 22, 2023

Contents

1   Introduction

Thank you for choosing the Delta 7 wavefront modulator from Phaseform GmbH and thereby taking a step forward with us towards a "New era of adaptive optics".

The Delta 7 is a transparent, continuous-sheet, spatial light modulator (SLM) which can modify the phase of the light up to the 7th radial order Zernike and is based our award-winning "Deformable Phase Plate" (DPP) technology. It is a novel device class of optical components which can be used in many fields and applications. We are always open to receive comments, corrections, and requests at info@phaseform.com.

Notes:

Before installing and operating the Delta 7, make sure to read and understand this user manual. The device may only be operated after thoroughly reading and understanding this document.

All information given in this manual is reliable to our best knowledge. However, no responsibility for possible inaccuracies or omissions can be assumed. Information and data contained in this documentation can be amended without notice. Specifications and external appearance are subject to change without notice.

2   Recommendations and warnings

2.1   Used Symbols and Signal

The following symbols and signal words are used in this user manual:

Danger: This warns of dangerous situations that might cause injuries or damages.

High Voltage: This warns of dangerous situations caused by high voltages.

Notice: This warns of situations that might cause damage to the device and or other devices attached to it.

Important: This provides important advice and useful information.

Hint: This provides useful hints for operating the device and software.

2.2   Validity and Version

In its current revision, this manual applies only to products of the series D7-E-22-XXXX. Should you require a manual from a previous revision, please contact Phaseform. Please let us know your electronics driver serial number, we will send you the appropriate manual as a PDF file.

Important: This user manual is only valid for a specific product line.

2.3   Application Purpose

General Description of the Device   The Delta 7 phase modulator system is an active, electro-optical component consisting of multiple parts and can perform different functions in various optical systems.

Intended use   The device is only intended for the use described in this user manual.

- The device must not be used as a medical device or for medical purposes.

- It must not be used within an optical system to diagnose, detect or treat any human medical condition, or perform any medical function.

- The device must not be used in any way that could be harmful to any human being.

A use for applications distinct from the intended purposes can lead to dangerous situations and is to be omitted.

2.4   Safety Advice

The Delta 7 has been developed and was manufactured to largely rule out issues for its intended use. Nevertheless, you must observe the following measures to prevent the remaining safety issues.

Installation

- The electrical installation must be in accordance with national standards and regulations.

- Cables must not be laid in a way that might cause a person to trip and fall. They should be clearly marked or covered if they are running through an area where people walk.

- The user is obliged to keep this manual in a safe place and to ensure that it is available to all individuals who may come into contact with the device.

Environmental conditions

- The nominal operating range of the device is $20\,°C$ to $25\,°C$ below $2000\,m$ altitude. Operation outside the operating range might cause reduced performance and even permanent damage.

- The optical element should be operated under its damage threshold of $<4\,W$ (CW on optical aperture of $\varnothing\,10\,mm$). Nominal operation of Delta 7 is tested currently only up to CW $60\,mW$.

- The driver unit is not intended for use in humid or wet environments. For this reason, make sure that the driver unit is always located in a dry environment.

- It is not allowed to use the devices in an explosive atmosphere or close to potentially explosive substances.

Safe operation

- The device and cables must be checked for damage before operation. The device must not be switched on if damage to cables or the outer hull is detected.

- The user must comply with all safety instructions that are given in this manual.

- The user is responsible for ensuring that the devices are used for their intended purpose and in accordance with the instructions given in this manual.

- The user must respect laws and regulations of the place of installation while operating the device. The user is responsible for compliance with all local, national and international regulations and standards that are relevant to the use of the devices.

- The user must be familiar with the operation of the optics hardware, electronics, and the control software.

- The user must ensure that persons not trained in the use of the devices do not operate it.

- To prevent charge accumulation, no actuation element of the Delta 7 should be at a fixed high voltage level for an extended period of time, i.e., avoid fixed phase profile target for greater than 5 minutes.

Maintenance and cleaning

- The surface may only be cleaned gently with a small air or nitrogen stream. Do not clean the optical unit with cleaning agents or chemicals. Warranty claims will not be accepted due to reduced performance or scratches caused by inadequate cleaning or handling.

- The safety of the user and a failure-free operation of the devices are assured only if original parts and accessories are used. Warranty claims will not be accepted for damage due to the use of non-original accessories or extensions.

High Voltage: Danger from electric current! Danger of fire! Do not use wet cloths to clean the unit.

Deactivating

- At the end of use the device must be switched off and disconnected from the power supply.

3   Delta 7 Specification

Hint: Specification Version 0.2.6: Specifications in this section of the manual are for reference with respect to the usage and handling instructions in the following sections. The specifications of your Delta 7 are provided as a separate document as part of the sales packet.

General specifications

Modulator type	Optofluidic Deformable Phase Plate (DPP). Electrostatic actuation.
Clear aperture diameter	$10\,mm$
Number of actuation elements	63
Number of actuators across aperture diameter	7
Connectivity	USB Serial
Operating system	Windows, GNU/Linux, and macOS
Driving software	SDK available in Python and Julia. Web-based UI
Mounting compatibility	$30\,mm$ cage system rods, SM1 inner threads
Included in the Delta 7 package	Driving electronics, control software, cables, manual
Electronics cable length	$1.5\,m$, optional: $0.3\,m$

Optical specifications

Wavefront RMS error of active best flat	$< 15\,nm$ (orientation independent)
Maximum peak to valley of the generated wavefronts	$> 8\,\mu m$ @$\lambda = 632\,nm$
Maximum spatial frequency of the correction	7th radial order of Zernike polynomial mode
Optical transmission without anti-reflection coating	$> 85\,\%$ at $\lambda = 550\,nm$
Damage threshold	$< 4\,W$ (CW on optical aperture of $10\,mm$
Nominal operation laser power	Tested up to CW $50\,mW$ on optical aperture of $10\,mm$

Mechanical specifications

Housing dimensions, weight	$(45.50 \times 59.75 \times 14.80)\,\text{mm}$, $61\,\text{g}$
Thickness in the clear aperture	$0.87\,\text{mm}$ $\mathbf{0.87\,mm}$
Linearity	$> 92\,\%$

Electrical specifications

Maximum input voltage at the modulator	$300\,\text{V}$ (per channel)
Maximum power consumption	$< 9\,\text{W}$
Power supply	$120\,\text{V}/230\,\text{V}$ AC, 3 pin DIN 41524 connector

Thermal specification

Storage temperature	$10\,°\text{C}$ to $35\,°\text{C}$
Operating temperature	$20\,°\text{C}$ to $25\,°\text{C}$

4   The Delta 7

4.1   Parts included in the Delta 7 package

- 1 Delta 7 optics unit

- 1 Delta 7 electronics driver unit

- 2 High voltage (HV) connector cables with 34-channels each

- 1 USB cable (USB A to USB B)

- 1 Power supply (DC out: 24V, max 1.7A ; AC in: 100-240VAC, 1A, 50/60Hz)

- 1 Country specific power cable

- 1 Printed user manual

- 1 USB stick (credit card format) including drivers and software package

- 1 Hex-Wrench 1.5mm

- 1 (optional) Post mounting adapter to mount the Delta 7 optics unit on a breadboard post with a M4 threading

4.2   Technical details

For a better integration into an already existing or new setup, consider the dimensions of the optics and the driver unit. All dimensions shown are in mm.
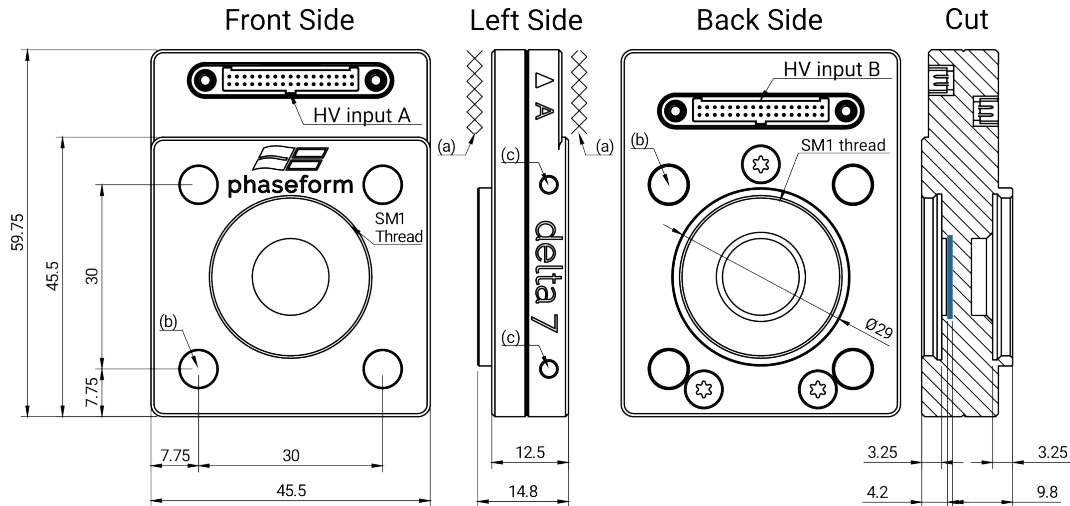
4.2.1   Optics unit

Figure 1: Delta 7 optics unit schematic with dimensions in millimeters.

Front side   The front side can be identified by the Phaseform logo located above the aperture. The HV input A is located on the front side. For mounting the optics unit, there is an SM1 thread available, as well as holes that comply with a 30 mm optics cage system with 6 mm rods marked with (b). The clear aperture is centered with respect to the rod intakes and the SM1 thread.

Left side   The side view shows the device name "Delta 7" as well as the label of the HV input. The arrow indicates the position of the connector. The letter next to the arrow indicates the connector name. On the left side, the HV input A is labeled, on the right side (not shown in the graphic), HV input B is labeled.
The crossed areas (a) on both sides of the device indicate a recommended free space of 40 mm to safely handle the cables. The side view shows also the two holes (c) where the whole optics unit may be fixed with set screws (M3 thread) on 6 mm optics cage rods.

> **Hint:** Remember that both cables must be connected into the device for it to operate. The device can not operate if only one cable is connected or both cables are disconnected. We propose a 40mm free space measured direction perpendicular to the front and rear of the device.

Notice: High voltage wires may be harmed by bending radii lower than 30 mm. Inoperable wires cannot be used to operate the device. If the cables exhibit any signs of damage, stop using them and contact support for replacement. Only use original equipment.

Back Side   The back side of the optics unit can be identified by the circular wall with an inner SM1 thread. The HV input B is located at the back side of the Delta 7 optics unit.

Cut view   The cut view illustrates the depth of the SM1 threads and the location of the Deformable Phase Plate (DPP) inside the Delta 7 optics unit. The DPP is shown in blue on the diagram. The rigid glass side of the DPP faces the metal housing's front side. The deformable membrane is located on the back side.

Hint: We recommend to use a protective window screwed on the SM1 thread on the back side to protect the membrane from dust and users inadvertently touching the membrane.

Notice: The flexible membrane is located on the back panel. Avoid touching the membrane to prevent dirt from adhering to its surface. The surface may only be cleaned gently with a small air or nitrogen stream without the use of cleaning agents or chemicals. Any mechanical stress applied to the membrane surface has the potential to cause permanent distortion, scratching or even piercing or tearing the membrane, potentially spilling the optical liquid, all of which voiding the warranty.

Important: Damage to the membrane can result in spillage of the optical liquid. If you notice membrane damage or liquid spillage, contact support, avoid touching the fluid with your bare hands, and avoid any body or eye contact or and inhalation. Use protective gloves and wear safety goggles while bagging damaged the unit in a air- and watertight container for disposal or return.

4.2.2   Electronic Driver Unit

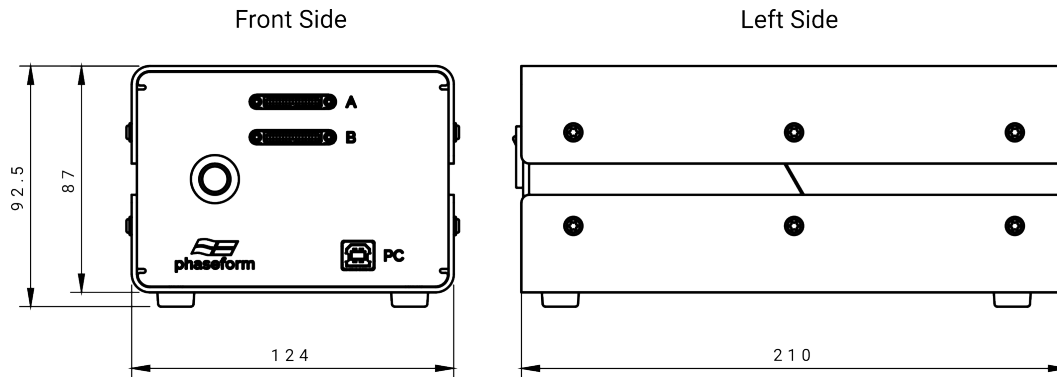Front Side   Left Side

Figure 2: Delta 7 electronic driver unit schematic with dimensions in millimeters.

For positioning the Delta 7 electronics driver unit, make sure that it is located on a even and stable ground. The rear and the front of the driver shall not be blocked so the switches, buttons, and plug connectors are easily accessible. The space is also needed for ventilation purposes. Do not apply mechanical load onto the driver unit.

> **Notice:** Do not block the ventilation slots on the rear. This might result in overheating and failure of the device.

> **Notice:** Modifications or additions to the electronics must not be carried out as they cause malfunctions and may create safety hazards. Electrical enclosures must only be opened by qualified service personnel. In such a case, the enclosures must be disconnected from power before servicing.

Accessories   The following accessories, as listed in subsection 4.1, are delivered in the standard set of the Delta 7.

HV connector cables   The 2 high-voltage connector cables relay the high voltages required to operate the optics unit. They must be connected to their corresponding HV connectors A/B.

USB cable   The USB cable connects the electronics driver unit to a computer's USB port.

Power supply The power supply provides the required power to the electronics driver unit. It provides a DC output of 24V, max 1.7A. The AC input to the power supply has to meet: 100-240VAC, 1A, 50/60Hz)

Power cable The power cable connects the power supply to the wall plug and is country specific.

User manual The user manual contains all information necessary to install, configure, operate, troubleshoot and maintain the device.

USB stick The USB stick contains the electronic version of this user manual, the latest version (X.X.X) of the controlling software ("dpp_ctrl-X.X.X-py3-none-any.whl") and the influence matrix of the pre-calibration at the time of shipping. To open the USB stick, hold the card with the Phaseform logo facing up. Gently bend the card and push the hole at the side downwards to flip the USB stick out of the card.

Hex-wrench This wrench is used to fix the connectors of the HV connector cables to the optics and electronics driver unit.

Post mounting adapter (optional) The post mounting adapter can be used to mount the optics unit on a optical post. This optional part might be contained in some shipments, on customer request.

4.3 Storage and Transport

The Delta 7 may not be stored or shipped at temperatures below $+10°C/50°F$ or above $+60°C/140°F$. This can cause permanent damage to the microfluidic optics. Please use only the original packaging for shipping or transporting the device. The thermally insulated shipping box maintains its temperature up to 72 hours during air transport. If the time of transport exceeds this limit, or the environmental conditions deviate from typical conditions encountered during air transport, the device may be damaged.
The device should be stored a dry, dark, and solvent-free environment.

5 Getting started

5.1 Hardware installation

This section describes how to install and set up the Delta 7 in a typical optical setup.
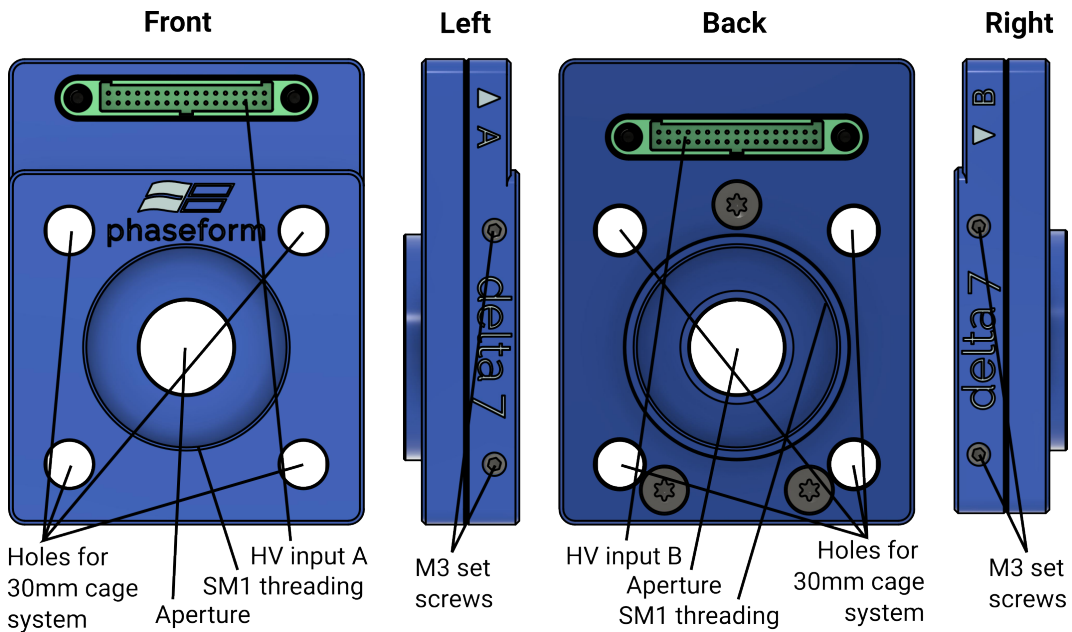

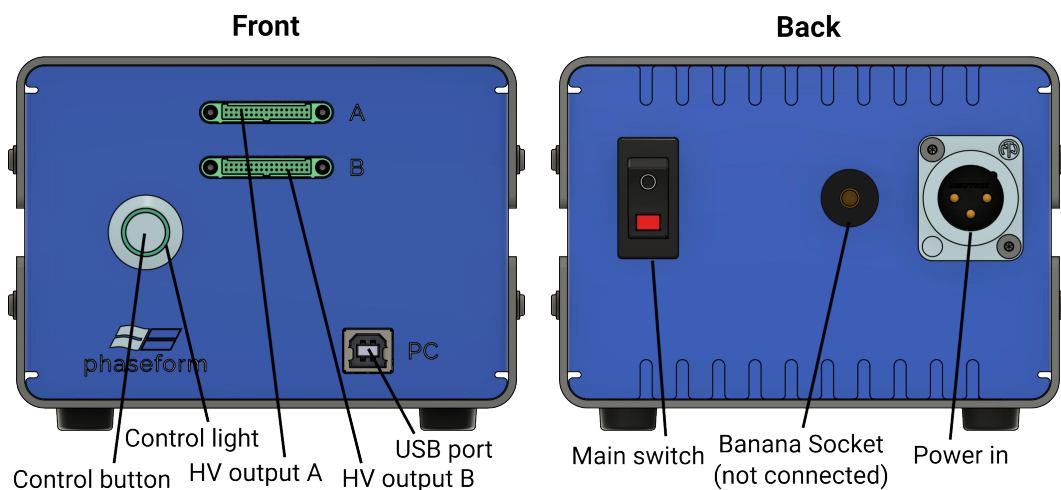Figure 3: Delta 7 Optics unit.

Figure 4: Delta 7 Electronic driver unit.

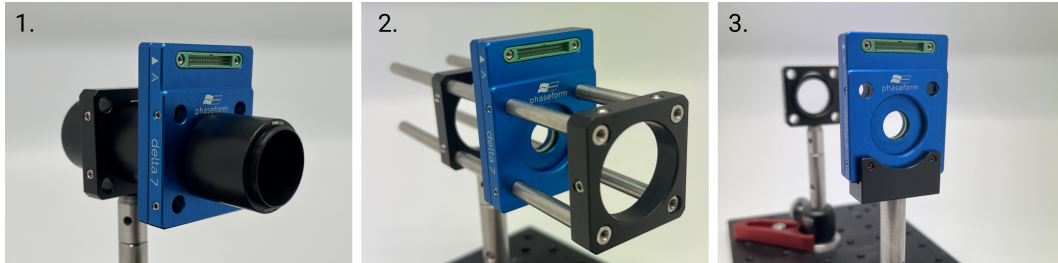**Hardware setup**   The Delta 7 can be integrated in an optical setup using one of the following options:

Figure 5: Possible mounting options for the Delta 7 : 1. SM1 threads, 2. 30mm cage system 3. using optional adapter to mount on an optics post

> **Hint:** The device comes pre-calibrated assuming light is entering from the front side and the orientation is upright (same as in Figure 5)

Connecting the optics to the driver unit   Place the driver electronics on a stable, even surface. Connect the driver electronics to the optics unit using the HV connector cables provided. Plug one high voltage cable into the HV output A of the driver and the HV input A of the optics unit (see Figure 6a)) and gently tighten the screws of the cable (see Figure 6b)). Use the provided screwdriver to fix the connectors to the plugs. Insert the other high voltage cable to the HV output B of the driver and HV input B of the optics unit. Gently tighten the screws of the cable (see Figure 6c)). The assembly Delta 7 is shown in Figure 6d). Connect the power supply to the power in socket at the driver unit. Use the provided country specific power cable to plug the power supply to the wall socket.
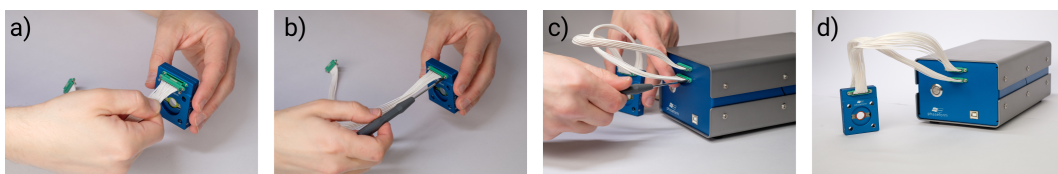

Figure 6: Connecting the Delta 7 optics and electronics driver units.

> **Important:** Always connect **A** to **A** and **B** to **B**. If the cables are connected in the wrong way, the device will not operate as intended.

Notice: The HV connector cable's screw lock torque may not exceed 0.18 Nm

Aligning the optics unit   The aperture of the optics unit has a diameter of 10mm. Only by utilizing the full aperture diameter will the Delta 7 be able operate at its maximum performance. Smaller beam diameters may result in significant loss of correction performance.

The alignment of the device in the beam path is identical to the alignment of an optical lens, the path should be perpendicular to the largest surface of the optics housing.

Hint: Plugging in or out, touching or moving the HV connector cables after alignment might move the device and realignment may be needed.

Operation orientation   The device can be operated in horizontal (beam path is vertical) or in vertical (beam path is horizontal) orientation. As the influence matrix for each orientation is different, depending on the orientation, the correct influence matrix has to be loaded.

Hint: For vertical operation, the performance is sightly reduced, since a fraction of the range is used for compensating the gravity induced coma.

5.2   Hardware usage

Turning on the Delta 7   After all cables are secured and the Delta 7 is correctly set up, set main power switch on the rear side of the electronics driver unit to ON. The control light around the control button on the front side will blink and cycle its colors through red, green and blue. The electronic driver unit is now in **system standby mode**.

Next, connect the driver to the controlling computer using the included USB cable. The computer will recognize the device.

Push and hold the control button until the alternating blinking control light becomes a constant blue light. This can take a few seconds. Then let go of the button. The control light will become constantly green after, and the device is now **system ready mode**.

Turning off the Delta 7   To shut down the Delta 7 , push and hold the control button for a few seconds until the green light starts blinking cycling through red, green and blue again. The device is now back in **system standby mode**. Switch off the main switch at the rear of the driver unit. If unused for a longer period of time, unplug all cables and safely store it in the provided box.

Hint: If the control light is blinking green after switching to **operating mode**, the HV connector cables are not properly plugged-in or fastened properly. Shut down the device, and re-connect the cables. If the issue persists, check for cable or connector defects. If you notice any defects, contact support for a replacement.

Hint: The Driver electronics is limited to $300\,\text{V}$ per channel by hardware design. In case of a hardware failure, a safety mechanism will kick-in and the driver will go to the error state (red control light).

Important: If the control light is blinking red, an error has occurred. Turn off the device using the main switch, wait for 10 minutes and restart the device. If the error is re-occurring, shut down the device, unplug it from the power source and contact support.

Important: If the device controller is unresponsive, the controller logic might be stuck in an undefined state. Turn off the device using the main switch, wait for 2 minutes and restart the device. If the error is re-occurring, shut down the device, unplug it from the power source and contact support.

5.3   Software installation

5.3.1   Prerequisites

1. Python interpreter + pip Instructions on installation and documentation can be found on the project's websites:

   - Python (version > 3.7): `https://www.python.org/`
   - pip (package installer for Python): `https://pip.pypa.io`

   Please check that you have a working installation of python interpreter with pip installed. This can be done by running the following commands and

making sure that the output looks similar.

GNU/Linux and MacOS:

```
$ python --version
Python 3.N.N
$ python -m pip --version
pip X.Y.Z from ... (python 3.N.N)
```

Windows:

```
c:> py --version
Python 3.N.N
c:> py -m pip --version
pip X.Y.Z from ... (python 3.N.N)
```

2. Internet connection (required for the installation command pip install) Python dependencies including open source scientific computation libraries will downloaded and installed automatically as part of the installation process.

3. The Delta 7 software is compatible with Windows 10, but libraries should be portable to GNU/Linux or MacOS platforms as well.

5.3.2   Getting the installation package

The software is shared as an installation archive on our public Gitlab repository at:
https://gitlab.com/phaseform/dpp-ctrl-installer

Figure 7: Screenshot of GitLab repository with the Python archive ("wheel" file) for local installation.

The git repository can be cloned to acquire all the files. Alternatively, only download the installation archive, the ***.whl** file, also highlighted in Figure 7.

Basic installation   Installation uses *pip*, the reference Python package manager. Documentation for using pip and virtual environments can be found in official project documents (see links in Section 5.3.1 and Installing packages using pip and virtual environments).
Consider the location/path of the downloaded ***.whl** file. The following commands in the *command prompt* or *terminal* can be used to install the required libraries and dependencies.
GNU/Linux and MacOS:

```
$ python -m pip install download_location/filename.whl
```

Windows:

```
c:> py -m pip install c:\download_location\filename.whl
```

Advanced installation   If using a Python distribution or some other non-standard setup, consider manual installation of the dependent libraries as recommended by your distribution. The software depends on a the following common open scientific libraries:

1. scipy

2. numpy

3. matplotlib

4. scikit-image

5. pyserial

For example with Miniconda or Anaconda:

```
conda install scipy numpy matplotlib scikit-image pyserial
```

Finally, install the Delta 7 control software as described in Basic installation.

License   The controlling library is licensed under the GNU General Public License version 3 (GPLv3).

5.4   Software Usage

5.4.1   Installation verification

To verify that the control library was successfully installed, run the following command:
GNU/Linux and MacOS:

```
$ python -m pip show dpp_ctrl
```

Windows:

```
c:> py -m pip show dpp_ctrl
```

This command returns information about the installed libraries and if the library has not been properly installed, it returns a warning.

```
% python -m pip show dpp_ctrl
Name: dpp-ctrl
Version: 1.0.0
Summary: GUI-based and OOP-oriented Python library for controlling of a DPP device
Home-page: https://gitlab.com/phaseform/dpp-ctrl-installer
Author: Sergei Klykov
Author-email: klykov@phaseform.com
License: GPLv3
Location: /tmp/phaseform/env/lib/python3.10/site-packages
Requires: matplotlib, numpy, pyserial, scikit-image, scipy
Required-by:
% ls /tmp/phaseform/env/lib/python3.10/site-packages/dpp_ctrl/calibrations/
20220422-FlatOffsets_63_1V_H63A_300.csv  Calibration.json         __pycache__
20220422-InfMat_63_1V_H63A_300.csv       create_calibration_json.py
%
```

Figure 8: The *pip show* command can be used to verify installation and check the location of the installed files. The included calibration files are found in the *"dpp_ctrl/calibrations"* sub-folder.

5.4.2   Launching the GUI-based control program

1. Start the Python interpreter

   GNU/Linux and MacOS:

   ```
   $ python
   ```

   Windows:

   ```
   c:> py
   ```

2. Import the Delta 7 software module in the Python console

   ```
   >>> from dpp_ctrl import gui_dpp
   ```

3. Launch the GUI-based program

   ```
   >>> gui_dpp.launch()
   ```

This launches the GUI in the **simulation mode**, that opens 2 windows:

1. Sum of Zernike polynomials:

2. Amplitude controls

Hint: In the simulation mode, no hardware connection to the Delta 7 is established and no calibration files are loaded. This also is shown in the bottom left selector ("Simulation" or "DPP Control")

You can also launch the GUI in a quick-start way, which automatically loads:

- Influence Matrix file

- Flat Field Correction file

and it tries to connect to the first, active COM / serial port available. Note that the timeout for connection to the electronics driver unit is approximately 4 seconds. The command for **quick-start mode** is:

```
>>> gui_dpp.external_launch()
```

5.4.3   Window 1: Sum of Zernike polynomials

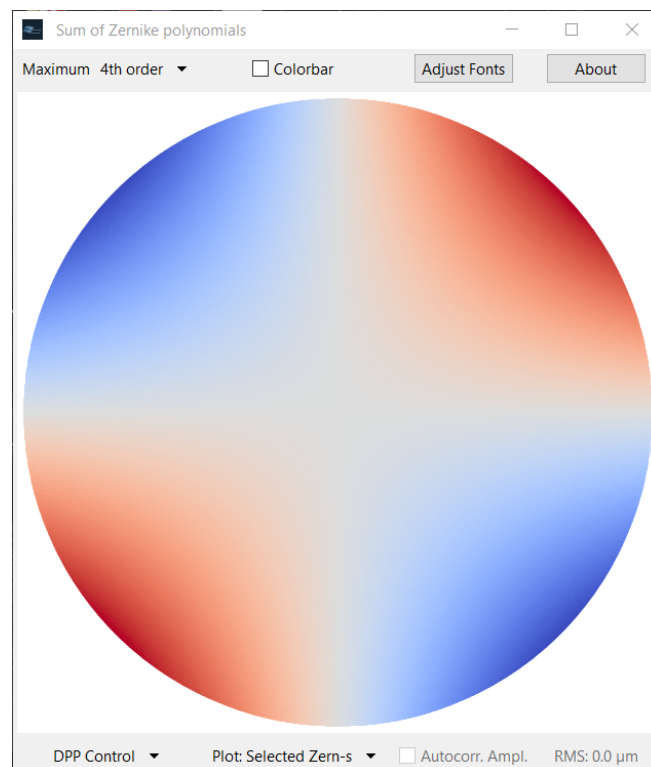The **Sum of Zernike polynomials** window shows surface profile of the Delta 7.

Figure 9: Sum of Zernike polynomials window. *Oblique Astigmatism* is displayed.

- **4th order ▾** allows selecting of the maximum order of controllable Zernike polynomials amplitudes

- **☐ Colorbar** turns the legend on/off for the surface profile

- **Adjust Fonts** allows to adjust font size / slider lengths / figure size for different monitor resolutions (experimental feature)

- **About** open a separate window with information about a program version and shortcuts that can be used when the Amplitude controls window (from 5.4.4) is selected

- **DPP Control ▾** connects to the Delta 7 electronics driver unit. Invokes *Window 3*, see Section 5.4.5

- **Plot: Selected Zern-s ▾** selects plotting either the phases profile selected by the user, or the phases profile that actually set to the connected device

- **☐ Autocorr. Ampl.** activates automatic correction of defined on the Amplitude controls window (from 5.4.4) polynomials amplitudes to the actually applied on the DPP values

- **RMS: 0.01 μm** shows the RMS error value between selected amplitudes of Zernike polynomials and the actually applied ones

> **Hint:** Last two GUI elements are activated when the plotting of Applied Zernike amplitudes has been selected

5.4.4   Window 2: Amplitude controls

> **Hint:** The unit of the target and applied phase amplitude is in μm optical path difference. This of course depends on the calibration data that is used. The software expects the calibration data to be therefore also in terms of μm optical path difference $@\lambda = 632\,\text{nm}$.

The **Amplitude controls** window provides a graphical way of specifying the amplitudes; either by use of sliders, or by text box inputs that accept values in the range $(-2.0$ to $2.0)$ μm. A complex phase profile described by a combination of multiple

Zernike modes can be applied using this interface. For precise control, consider the use of scripting API (see Section 5.4.6). The examples of both windows variants are shown below:
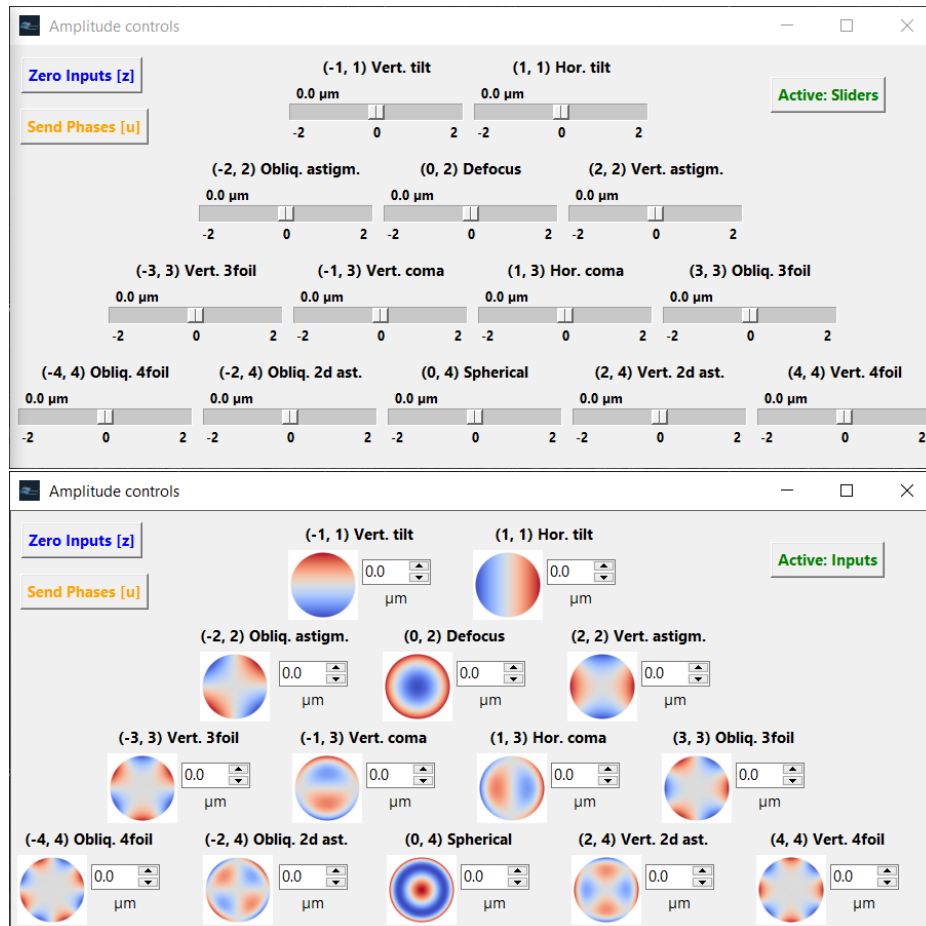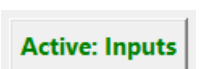
Figure 10: Amplitude controls window. Slider input (top), text input (bottom).

Both windows share the two following buttons:

- **Zero Inputs [z]** zeroes all Zernike polynomials amplitudes / flattens the surface profile but it doesn't send the zeroed amplitudes to the device

- **Send Phases [u]** sends selected amplitudes to the connected device

- **Active: Inputs** switches between sliders and numerical value inputs. In the

latter, next to the numerical input is a rendering of that specific Zernike polynomial

5.4.5   Window 3: DPP control panel

The **DPP control panel** window is intended for DPP device controlling. This windows is invoked from *Window 1* (Section 5.4.3).
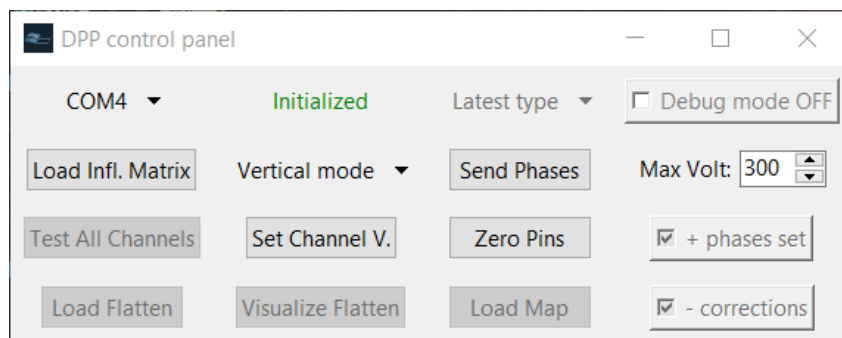
Figure 11: DPP control panel window. Includes options to select connection port and loading calibration files for operating the Delta 7.

Button functions are described below:

- COM4 ▼   selects the computer COM / serial port

- Initialized   shows the initialization status of the connected device to the selected COM port.

  Hint: If the selected COM port does not initialize the device (will show "Not initialized" in red letters), try another COM port from the list.

- Load Infl. Matrix   loads an Influence Matrix file. It accepts **json*, **csv*, **mat*, **pkl* extensions. If you are unsure of the location of the installation folder, you can check it by running the command `pip show dpp_ctrl` (see Section 5.4.1)

  Hint: The Delta 7 requires calibration for its operation. Calibration files translate target physical membrane deformation to required actuation voltages that are delivered by the electronics driver unit

> **Hint:** Each Delta 7 comes **precalibrated** with:
> one single *json* file composing all calibrations;
> 2 separate sets of calibration files with *csv* extensions, one for horizontal and one for vertical operation

> **Hint:** Creating customer-specific calibration files is outside the scope of this manual version and will be added in a later release.

- **Send Phases** sends the surface profile (set of Zernike polynomials) shown on the window "Sum of Zernike polynomials" to the Delta 7

- **Vertical mode ▼** allows switching between calibrations (an influence matrix and flat field corrections) related to vertical or horizontal modes loaded from a single *json* file

- **Zero Pins** sets all voltage channels to 0 Volts

> **Hint:** If you set all channels to 0 V the flat field corrections are not applied, and there will be residual aberrations

- **Load Flatten** load a calibration file with a flat field correction. This button will be activated if the Influence matrix had been loaded from the separate file (e.g., from *csv* file).

> **Important:** You will need to load both Influence Matrix and Flat Field correction after you initialize connection any (new) Delta 7. It can be done by loading single *json* file or separate files (e.g., *csv* files). The "Send Phases" button will not be available unless you load the Influence Matrix to the program.

5.4.6   Getting started with Python scripting

The Python library may be accessed and used via a Python console or as part of a script to directly control the Delta 7 . The api_dpi module includes the requisite class and its methods and can be imported as follows:

```
>>> from dpp_ctrl import api_dpp
```

Next the class can be initialized:

```
>>> pydppctrl = api_dpp.initialize()
```

Verbose debug messages may be enabled as follows:

```
>>> pydppctrl = api_dpp.initialize(verbose_debug_info=True)
```

API Methods

A list of available methods in the module are listed with their description below. Up to date description of the functions can be found in the API dictionary (api_dpp.html).

- `connect_device(port_name: str) -> bool`

  Initiates the serial communication with the Delta 7 . The serial port name as a string, for example "COM1" in Windows, is a required argument. This method returns a boolean value with the result of the call.

- `load_infl_matrix(abs_path: str = "",`
  `                  load_default: bool = False,`
  `                  operation_mode: str = 'v') -> bool`

  The function will load a file with the influence matrix (calibration data) in json, csv, mat file format at the absolute path provided as an argument. If the given path is an empty string, the `load_default` flag will be checked for further action.`load_default = False`: will open a file chooser to select a file; `load_default : True`: will use default calibrations stored in the installation folder. `operation_mode: str`: specify the two possible operation modes: 'v' - for vertical mode, 'h' - for horizontal one. This parameter is used only when the influence matrix loaded from the json file. The operation mode designates the two possible variants of the DPP installation in the optical system. This method will return True, when a correct influence matrix is loaded. `False` return value means an error which will be shown in the console.

- `load_flat_field(abs_path: str = "",`
  `                 load_default: bool = False,`
  `                 operation_mode: str = 'v') -> bool`

  Function similar to `load_influence_matrix` and parameters `load_default` and `operation_mode` work the same way. This method loads flat field corrections or calibrations offsets (json, csv or mat) from the provided file path. The method returns True on success.

- apply_phases(phases,
                          phases_plus: bool = True,
                          aberrations_plus: bool = True,
                          flat_field_minus: bool = True)

  Actively operates the Delta 7 to a target phase profile. The target profile is set in phases; can be a dictionary in format amplitudes values with OSA integer index {1: 0.1} or tuple with azimuthal / radial order {(1, 1): 0.1}. Alternatively, it can be a list with amplitudes/coefficients in OSA indexing order for Zernike polynomials, eg. [0.0, 0.1, 0.1, 0.0, -0.2]. The flags aberrations_plus and flat_field_minus can be used to switch the sign of the applied phase profile and correction field (for example because of device orientation).

- set_channel_voltage(channel_index: int = -1,
                          voltage: int = -1)

  This method allows settings voltage to an individual channel of a Delta 7 . Channel 1-63 can be selected by setting channel_index. Voltage (voltage) can also be set. If channel and/or voltage are not provided, a dialog window will appear for user configuration.

- launch_test_loop(without_confirmation: bool = False,
                          delay_time_ms: int = 250)

  This method can be used for diagnostics. It will set each channel one at a time to a maximum voltage. Flag without_confirmation when true will loop through each channel with a delay (delay_time_ms in milliseconds). Otherwise a confirmation window will pop up after each step.

- load_precalibration(operation_mode: str = 'v') -> bool

  Default calibration data is loaded from the single json file located in the installation folder. The operation_mode parameter allows switching between precalibrated data (the influence matrix and the flat field corrections) for two possible operation modes: vertical or horizontal, that is defined by the mounting of the DPP device in a optical system. This methods returns True when successful.

- zero_outputs(print_status: bool = True)

  Set zero to all output channels. Flag print_status enables verbose output to the console if the instance class was initialized also with the flag verbose_debug_info=True.

- close()

    Resets driver and closes all open resources.

Example script

The following is an example of the script-able control interface to operate the Delta 7 . The commands can be typed within a python console or executed as a script:

```python
from dpp_ctrl import api_dpp
import time
from pathlib import Path

# Configure COM port used for serial communication
port = "/dev/ttySUB0" # Windows: "COM4"

# Absolute path to calibration file
cal_file = Path("~/.virtualenvs/dpp_ctrl/lib/python3.10/"\
                "site-packages/dpp_ctrl/calibrations/"\
                "Calibration.json").expanduser()

# Limit electronics Driver maximum
VMAX = 300


def init():
    # initiliaze
    dpp = api_dpp.initialize()
    opened_flag = False

    if dpp.connect_device(port_name=port):

        dpp.set_max_voltage(VMAX)    # default is also 300
        dpp.zero_outputs()  # zero all outputs to 0V

        # load calibration
        # no argument launches file chooser
        if dpp.load_infl_matrix(str(cal_file)):
            opened_flag = True
    else:
        print("Could not connect!")

    return dpp, opened_flag
```

```python
def main():
    # run intialization and load calibration
    dpp, opened = init()

    if opened:

        # set amplitude of target modes
        phases = {(2, 2): 0.5,
                  (-2, 2): -0.5}   # m,n: amplitude
        dpp.apply_phases(phases)

        time.sleep(5)   # 5 sec delay

        # set amplitude of target modes
        phases = {(2, 0): 0.5,
                  (-2, 4): -0.5}
        dpp.apply_phases(phases)

        # approximated shape of DPP wrt. target
        print(dpp.get_approx_ampls())

        time.sleep(5)

        # test DELTA7. Loop through each channel
        dpp.zero_outputs()   # zero all outputs to 0V
        dpp.launch_test_loop()

        time.sleep(5)

    dpp.close()


# Run this script
if __name__ == "__main__":
    main()
```

This script initiates connection to the Delta 7 over the provided COM port and loads the calibration data from the file path. Specific target phase modulation can be applied by providing the Zernike mode indexes and amplitudes as a dictionary. The `launch_test_loop` method can be used to test the Delta 7 by probing each actuation channel with maximum voltage.

GUI scripted control

As an further feature, the GUI-based program can be launched as an independent Python *Process* that "listens" to calls from a separate python script/process. This features makes use of [Python multiprocessing queues]().
The following initialization call is required:

```
>>> from dpp_ctrl import gui_dpp
>>> ctrl_dpp_prc = gui_dpp.IndPrcLauncher(mpQueue)
>>> ctrl_dpp_prc.start()
```

Here `mpQueue` is a an instance of Python `multiprocessing.Queue` that accepts the aberrations specifications by use of function:

```
mpQueue.put_nowait(phase_dictionary)
```

The target phase profiles (`phase_dictionary`) should be defined in form of Python dictionary or a list. Format is described as follows:

- Dictionary: `{"0, 2": 0.1}`

  Key is a string in format *"azimuthal mode, radial mode"* and the value is the coefficient amplitude. Example above applies 0.1 defocus.

- List: `[0.0, 0.0, 0.0, 0.1]`

  List of Zernike coefficient amplitudes as per the OSA indexing scheme. Example above applies 0.1 defocus.

The GUI is open in a separate process thread and can be interacted with directly as per usual. The "EXIT" command can be passed to the queue to close and end the process. A full example is presented below:

```python
from multiprocessing import Queue
from dpp_ctrl import gui_dpp

mpQueue = Queue() # define Queue
ctrl_dpp_prc = gui_dpp.IndPrcLauncher(mpQueue)
ctrl_dpp_prc.start() # start GUI process

phase_dictionary = {"(-3,3)": 0.5, "(-2, 2)": -0.5}
mpQueue.put_nowait(phase_dictionary) # send target phases

mpQueue.put_nowait("EXIT")
```

6 Point of contact

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7   Version history

Version 0.1.1 Initial release (Draft). Date: September 14, 2022
Version 0.2.1 **Draft, not for commercial use**. Date: September 30, 2022 Added: Chapter Python scripting, Basic specifications.
Version 0.2.2 **Draft, not for commercial use**. Date: October 19, 2022 Added: Corrections in Python scripting.
Version 0.2.3 **Draft, not for commercial use**. Date: November 15, 2022 Added: API dictionary. Sync API references and added example.
Version 0.2.4 **Draft, not for commercial use**. Date: November 15, 2022
Version 0.2.5 **Draft, not for commercial use**. Date: January 23, 2023
Version 0.2.6 **Draft, not for commercial use**. Date: January 31, 2023 Update open-source license reference. Symbols and Signals refined. Warning texts clarified.

8   Software licenses

Delta 7 makes use of a number of open source softwares. The Python control software, "dpp-ctrl" is published under GPLv3 (https://gitlab.com/phaseform/dpp-ctrl-installer).
The Python module has the following dependencies. The respective open-source licenses can be found on their respective project pages:

1. Python and its Standard Library: PSF License

2. Matplotlib: Matplotlib license (PSF-based)

3. Scipy: BSD 3-Clause "New" or "Revised" License

4. Numpy: BSD 3-Clause "New" or "Revised" License

5. Scikit-image: MIT / BSD-based licenses

6. PySerial: BSD-3-Clause-based License

The Delta 7 electronics driver uses the Atmega 328p microcontroller that is flashed the Arduino bootloader. The following are the relevant open-source project used:

1. Arduino bootloader: GPLv2 based license

2. AVR-GCC: GCC Exception to the GPL

3. AVR-libc: Modified BSD License