High Voltage Digital Driver Software

User's Manual

For Software Version 6.2

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Warning

High Voltage Digital Driver (HVDD) Software applies voltage to the drive and Deformable Mirror (DM) **immediately** after selection, no other keystrokes required. Use high voltage safety procedures with both software and hardware.

See **Appendix B – Safety and Handling of Drive and Deformable Mirror** for tips on proper operation and handling of high voltage drives.

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1 Introduction

HVDD is an AgilOptics designed software product that allows the user to place a separate voltage on every actuator of an AgilOptics deformable mirror. HVDD can interface with all of AgilOptics' current deformable mirror drives such as the D40DI or the D64USB. HVDD features:

- Open-loop control (manual operation)
- Independent control of every actuator
    - Voltages ranging from 1 volt to 300 volts are driven on each actuator. The user may apply the target voltage to a single actuator, a group of actuators or to all the actuators of the mirror.
- Creation of and control for groups of actuators
    - The user can group actuators so that each actuator within a group will have the same voltage. These groups are dynamic and interface with other portions of the software.
- Creation of patterns for control by HVDD's sequencer
    - Users may create their own patterns with varying voltages for each actuator. Users are able to save and load these patterns into the sequencer. The Zernike Aberration patterns are an example.
- Multiple drive to PC interfaces
    - After installation of the software, the PC will communicate with the drive using either a parallel or a USB connection.

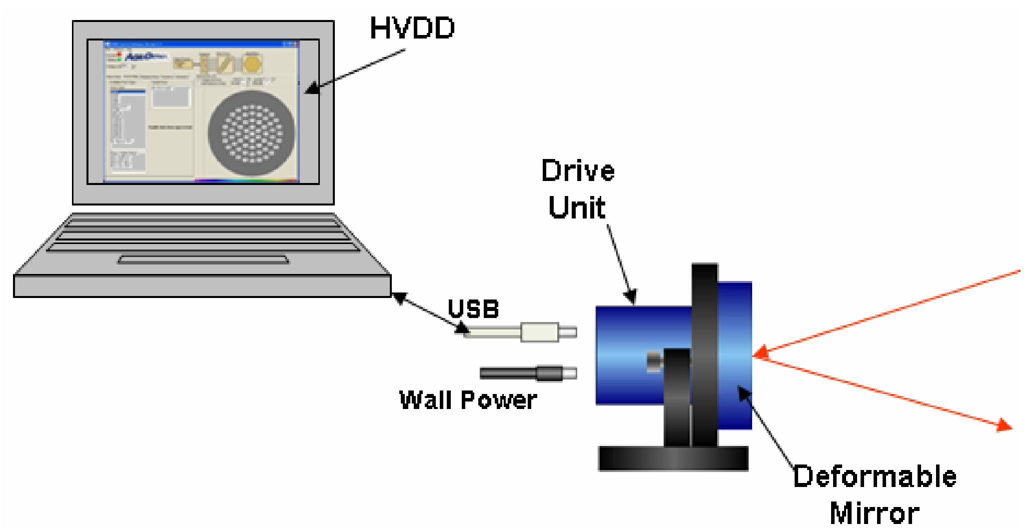

Figure 1: Functional Block Diagram of HVDD in Operation

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Requirements for HVDD

- 500 MHz CPU
- Windows XP
- USB 1.0
- 256 MB of RAM
- 10MB of available hard disk space
- 800x600 or higher-resolution video adapter and monitor
- CD-ROM or DVD drive

Recommended for HVDD

- 800 MHz or faster CPU
- Windows XP
- USB 2.0
- 512 MB of RAM
- 10MB of available hard disk space
- 800x600 or higher resolution video adapter and monitor
- CD-ROM OR DVD-ROM

1.1 New Features in Version 6.2

HVDD software version 6.2 includes a change to the **Rings** grouping feature. This change consists of the software detecting the type of pad array (mirror) loaded and switching the **Rings** grouping feature to **Rows** if the pad array is not circular (See Section 3.7).

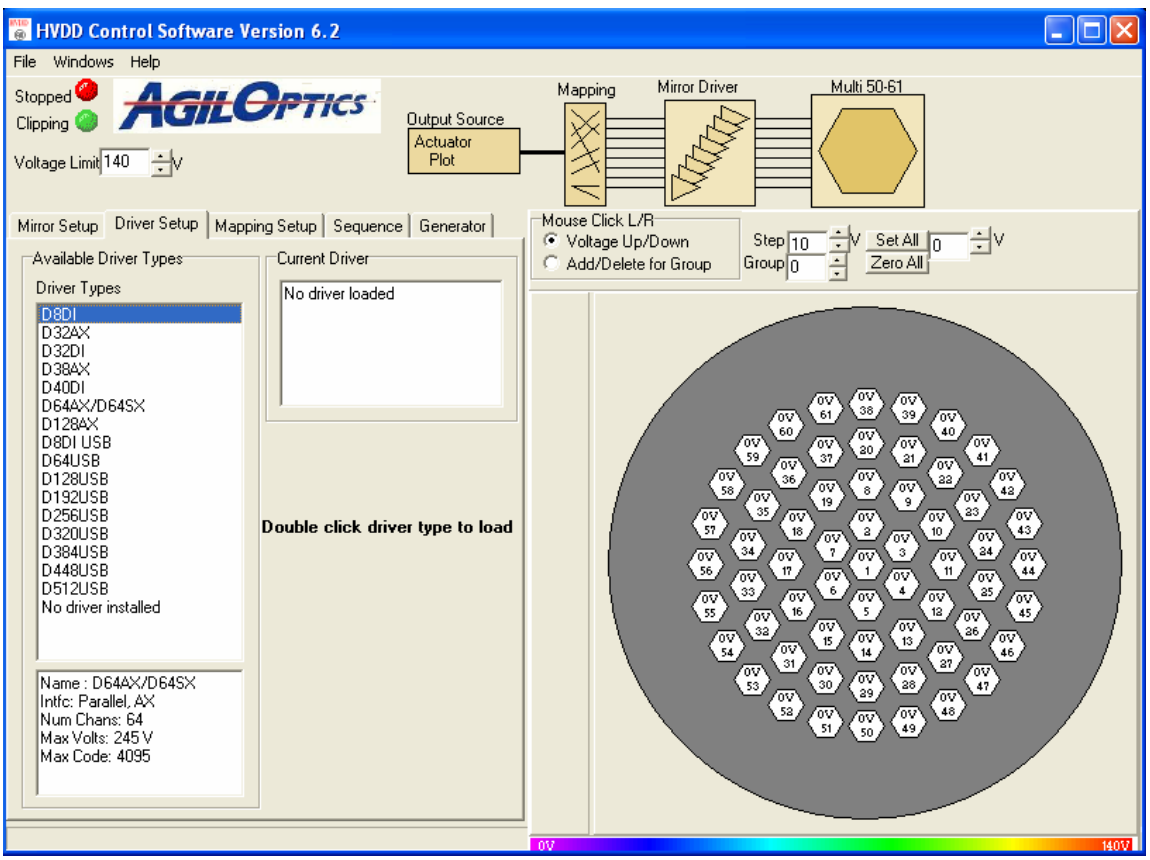

Figure 2: Overview of HVDD GUI

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1.2 Deformable Mirrors

Figure 3 shows a cross section of a typical deformable mirror made by AgilOptics. Charging the actuator pads creates an attractive force that pulls the on the mirror membrane. A desired optical shape is formed by manipulating the charge in different locations and strengths.

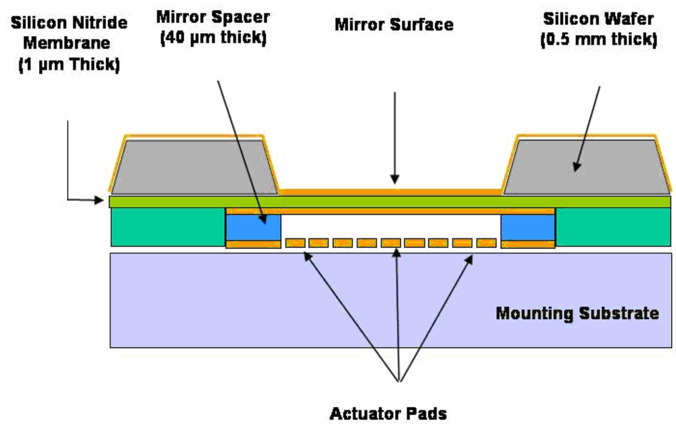

Figure 3: Cross section of an AgilOptics' Deformable Mirror

1.2.1 What Are Deformable Mirrors?

Deformable Mirrors (DMs) are adaptive optics that can change their optical properties in response to control signals. DM's have dynamic faces able to optimize reflected light for a specific application. DMs can focus and optimize a laser beam on a fixed point, replacing a lens, or focus a beam on multiple points at different times. Deformable mirrors improve optical images in telescopes, cameras, and other imaging systems.

A standard long-range surveillance camera with a telephoto lens will record a distorted, fuzzy image due to wavefront aberrations in atmospheric density between the camera and the subject. An extreme example of this effect is a mirage observed above a blacktop road on a hot day. A deformable mirror can remove these "wrinkles" in the wavefront to clarify the image and improve resolution.

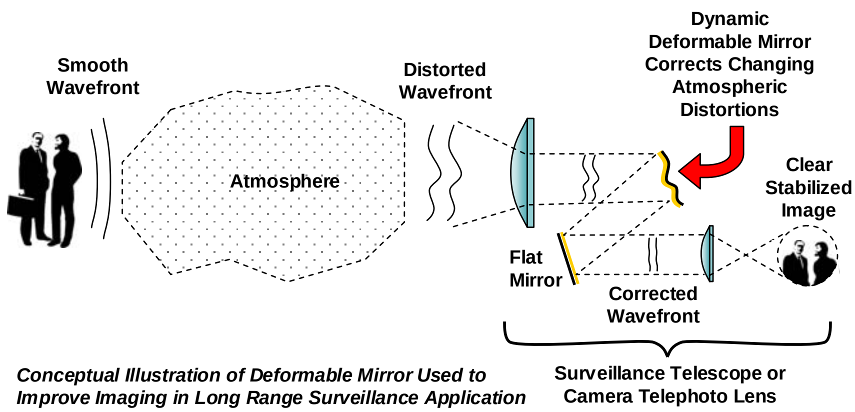

Figure 4: Atmospheric Aberration Correction

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Imperfections in the laser beam significantly reduce the ability to keep the beam tightly focused at extended ranges. Most lasers, particularly higher power devices, create an output beam with a less-than-perfect wavefront and "hot spots" (intensity variations) within the beam. A deformable mirror placed at the laser output can correct most of these imperfections and enhance the characteristics that make lasers desirable. By replacing one of the fixed mirrors within the laser cavity with a DM, even greater improvements in performance are possible.
Deformable mirrors can continuously change their shape up to several thousand times per second. High-speed changes on the mirror face allow for corrections in atmospheric distortion, laser cavity characteristics, or the twinkling of stars in astronomical telescopes.

1.2.2 What Can Deformable Mirrors Do?

- Correct Optical Aberrations
- Laser Beam Shaping
- Optical Image Enhancement

Deformable mirrors have the potential to revolutionize laser and optical systems. Some applications are listed here.

Optical Communications – Free-space optical communication concepts provide wireless links that are covert (cannot be intercepted), un-jammable, and low power when compared to radio-frequency alternatives. DMs can be used to reduce the beam divergence, which reduces the size and power of the laser transmitters – and compensate for atmospheric distortion. Operational uses include satellite communication – space-to-space, space-to-aircraft, and space-to-ground - and "last mile" data transmission to link fiber optical trunks to end-user equipment.

Laser Rangefinders, Designators, and Trackers – Hardware, ranging from hand-held to aircraft-mounted systems, could benefit from DM laser beam improvement to increase effective range and/or reduce physical size and electrical power requirements of the laser.

Surveillance Imaging Systems – Whether used for direct viewing or video camera monitoring and recording, surveillance systems could benefit from the real-time atmospheric distortion and vibration compensation afforded by an active deformable mirror.

Large-Aperture Cameras – The cost of large, high-quality lenses required for long-range, high-resolution, low-light cameras (film, digital and video) is prohibitive for many applications and users. If the optical system includes a deformable mirror to correct lens aberrations, the lens elements can be of much poorer quality and, hence, lower cost.

Biomedical Imaging – Several types of imaging instruments are used in the biomedical field. Many could benefit from improved focus, clarity, and resolution. The ophthalmoscope, for example, is used to image the eye's retina for diagnosing various diseases and conditions. The

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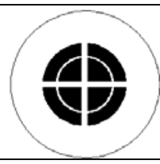
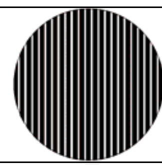
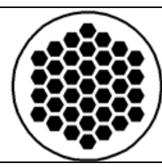
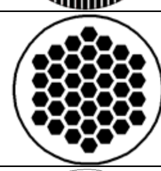
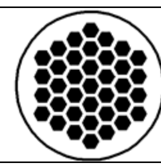
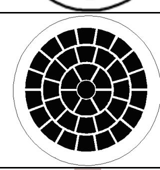
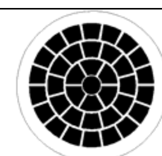
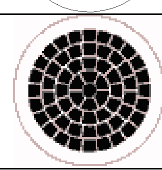
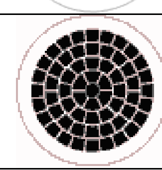
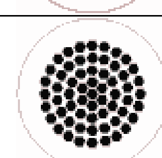
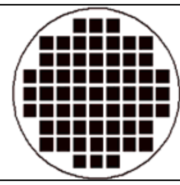
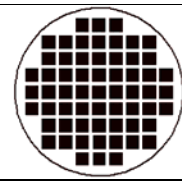
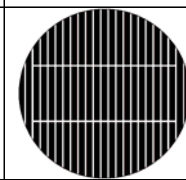
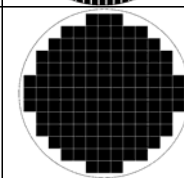
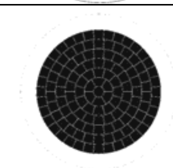
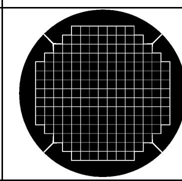
quality of the retinal image is reduced by the optical aberrations and imperfections of the eye's lens. Experiments with DMs have shown diagnostically significant improvement in ophthalmoscope performance.

Space Observation and Photography - One of the first applications to turn to deformable mirrors was the field of astronomy. The atmosphere not only causes the stars to twinkle but also distorts images of the planets and space vehicles. Several modern telescopes built with deformable mirrors provide previously unattainable performance.

1.2.3 Mirror Actuator Layouts

The following chart shows our mirror layouts, each darkened area is an area of individual control. Other layouts, sizes and actuator counts are available on special request.

	10 mm	16 mm	25mm	30 mm	50 mm
Ophthalmology					
36 Linear					
37 Hexagonal					
37 Concentric Circle					
61 Concentric Circle					
61 Circular Hexagonal					

	10 mm	16 mm	25mm	30 mm	50 mm
61 Rectilinear					
61 Linear					
121 Rectilinear					
127 Concentric Circle					
185 Rectilinear w/ Tip/Tilt					

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2 HVDD 6.2 Quick Start Tutorial

2.1 Installing HVDD

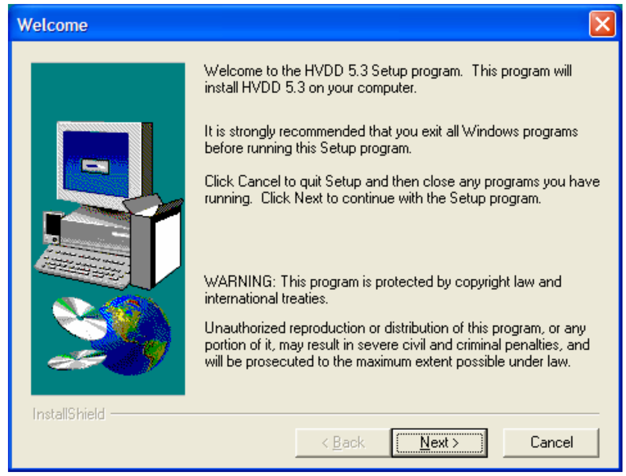

Figure 5: Installing HVDD

The installation file for HVDD 6.2 are included on a CD-Rom. The install files are also available for download at www.agiloptics.com.

1) Locate the file **AgilOptics_Install.exe** on the CD-Rom or within the HVDD 6.2 folder.
2) Click on **AgilOptics_Install.exe** to begin installation.
3) Follow the on-screen instructions.
4) Before running HVDD, plug the drive into the computer.
5) Start the program by either clicking on the HVDD icon on the desktop or the HVDD link in the Start Menu (See Figure 6).

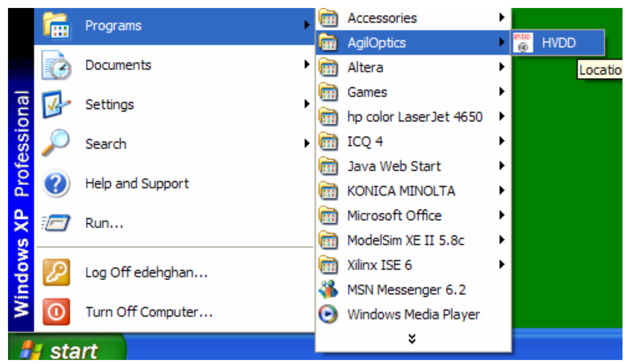

Figure 6: Location of HVDD on Start Menu

2.2 Getting Started

1) Double-click on the HVDD link to start HVDD 6.2.
2) The **Mirror Setup** tab will be active when the software starts. Double-click the type of mirror from the list displayed in the Mirror Types box.
3) Once a mirror is chosen, the **Driver Setup** tab will activate. Double-click the drive unit.
4) Click on the **Sequence** tab.
5) Adjust any of the slider bars in the **Aberration Adjust** list. The **Pad Array Diagram** will change colors indicating voltage change.
6) Congratulations! You are now in control of an AgilOptics' high voltage drive.

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3 Users Guide

3.1 Loading Mirror and Driver Files

1) Double-click on the HVDD link to start HVDD 6.2.
2) The **Mirror Setup** tab will be active when the software starts. Double-click on a pad array design or actuator layout from the list displayed in the Mirror Types box (See Figure 7).
3) Once a mirror is chosen, the **Driver Setup** tab will activate. Double-click on the AgilOptics drive currently connected to the computer (See Figure 8).

When the "mirror" or driver type is selected, there is a slight delay as HVDD opens the file.

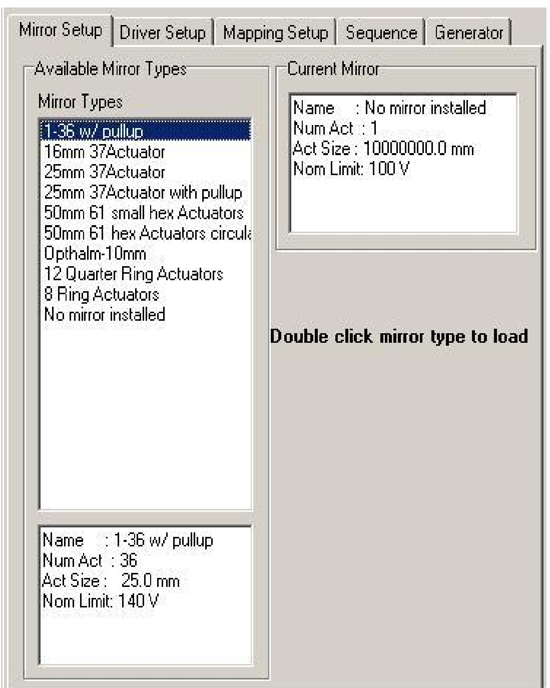

Figure 7: Mirror Setup Tab

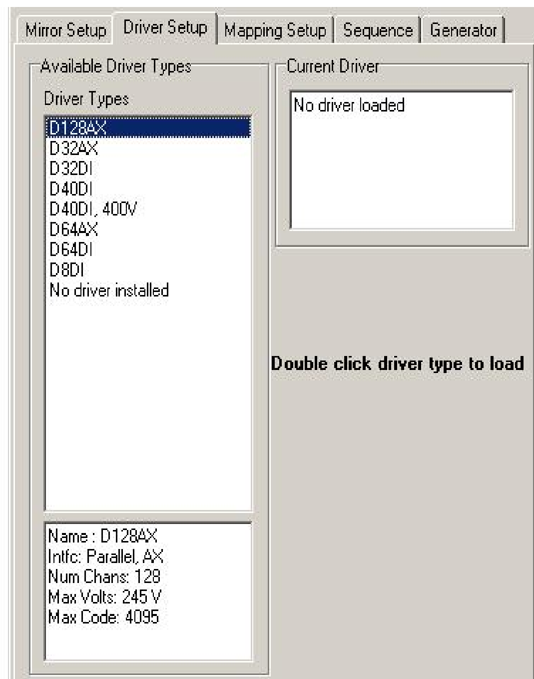

Figure 8: Driver Setup Tab

3.2 Voltage Limit

Figure 9: Voltage Limit Panel

The **Voltage Limit** box takes input from the user and provides a system-wide voltage limit on all the actuators. If the Voltage Limit is exceeded, the green lower light will

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turn yellow. This indicates that the voltage is being clipped on an actuator that is trying to increase past the set Voltage Limit or decrease below zero.

The red upper light indicates that actuator sequencing is off. When a pattern is running on the mirror, the upper light will turn green and "Running" is displayed to the left of the light.

3.3 Current Configuration Diagram

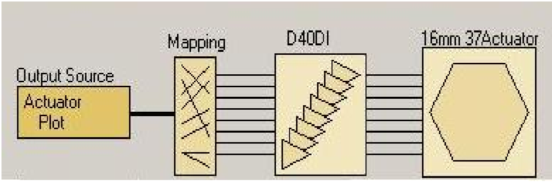

Figure 10: Current Configuration Diagram

The Current Configuration Diagram (See Figure 10) displays the mirror and driver information chosen under the **Mirror Setup** and **Driver Setup** tabs. Clicking once on any of the icons will open the respective tab. Double-clicking on the **Mirror Icon** launches the **Voltage Plot** window. The **Voltage Plot** displays and interacts exactly the same way as the **Pad Array Diagram** (See Section 3.6).

3.4 Actuator Control

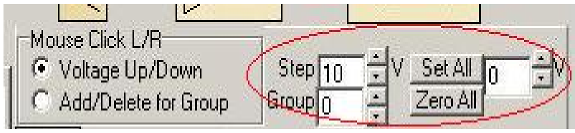

Figure 11: Actuator Control Panel

This portion of the user interface sets how clicking on the **Pad Array Diagram** affects an actuator.

- **Step** sets the voltage change, both up and down, when clicking on the **Pad Array Diagram**.
- **Set All** outputs the voltage specified in the box to every actuator on the mirror.
- **Zero All** sets all actuators to 0 volts.
- **Group** allows the user to add actuators to a defined group (See Section 3.7). This is used in conjunction with the **Pad Array Diagram Settings.**

3.5 Pad Array Diagram Settings

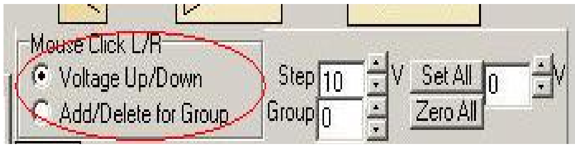

Figure 12: Pad Array Diagram Settings

The two radio buttons listed in the Mouse Click L/R box set the function of the Left and Right mouse button when interacting with the **Pad Array Diagram**.

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- **Voltage Up/Down** will set clicking on the **Pad Array Diagram** to change the voltage on an actuator.
- **Add/Delete for Group** will set clicking on the **Pad Array Diagram** to group editing, see Section 3.7 for details.

3.6 Pad Array Diagram

The **Pad Array Diagram** (See Figure 13) shows the user any voltage patterns placed on the mirror. The **Pad Array Diagram** is used to adjust voltages on specific actuators, or to create groups. A single-click on an actuator adjusts the voltage up (left-click) or down (right-click). If the group radio button (See Section 3.5) is selected, the user can add (left-click) and remove (right-click) actuators enabling the user to make custom groups (See Sections 3.6 and 3.9.1).

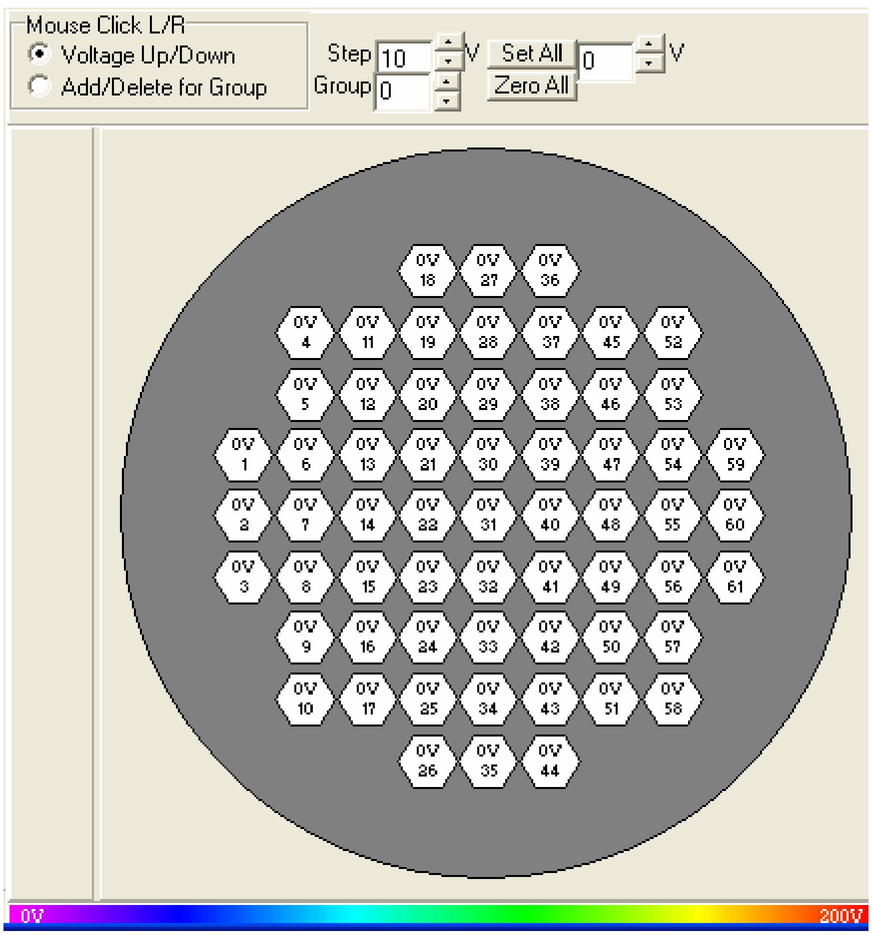

Figure 13: 25-61 Rectangular Loaded Onto the Pad Array Diagram

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3.7 Mapping Setup

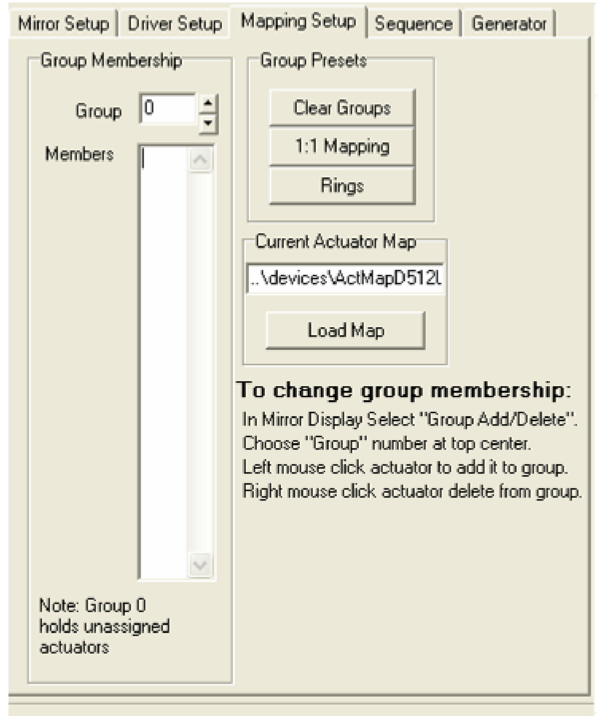

Figure 14: Mapping Setup Tab

The **Mapping Setup** tab (See Figure 14) allows the user to group actuators into control groups. Each actuator within a control group has the same voltage. Clicking any one of the grouped actuators on the **Pad Array Diagram** changes the voltage applied to all the actuators in the group.

Running the function generator or pulse loop on the **Generator** tab will likewise operate all actuators in a given group.

Group Membership Window

This window displays the current groups. Typing a number or clicking on the arrows next to the **Group** box shows what actuators are associated with a given Group.

Group Presets

- **Clear Groups** removes all current group mappings.
- **1:1 Mapping** returns the control map to the default state with one actuators per group.
- **Rings/Rows** makes each rings or row of actuators a single control group. The button is **Rings** when a pad array design is chosen (grey section of **Pad Array Diagram** is circular). The button is **Rows** when a channel layout (grey section of **Pad Array Diagram** is rectangular) is chosen in the **Mirror Setup** tab. Note: Custom layouts are possible for both pad array designs and channel layouts.

Current Actuator Map

HVDD loads a data file that ties the graphical **Pad Array Diagram** on the screen to the outputs on the driver. The box labeled **Current Actuator Map** shows the file that is loaded and

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running. This file is automatically loaded once a mirror and driver are chosen. The user may override the installed mapping file by clicking on the **Load Map** button.

3.7.1 Actuator Grouping

Follow the steps here to create custom actuator groupings. By default, all actuators are set to 1:1 Mapping (each actuator in its own group).

1) Click the **Clear Groups** button.
2) Select **Add/Delete for Group**
3) Select the group number in the **Group Membership** box.
4) Left-click on an actuator displayed in the **Pad Array Diagram** to add that actuator to the current group. The actuator number is displayed in the **Membership** box.
5) Repeat steps 3 through 5 until the groups are completed.

Notes:

- Right-click on an actuator to remove it from a group.
- Any un-grouped actuator will be set to group 0.
- The same procedures may be used with the **Voltage Plot** using the **Group** box.
- <u>Actuators may belong to only ONE group at a time</u>. If while making a new group a actuator in another group is selected, the actuator is deleted from the old group and placed in the new group.

3.8 Group Visualization Bar

The colored bar below the **Pad Array Diagram** (See Figure 15) shows the voltage colors. Clicking on this bar will toggle the mode between Voltage Gradient Color Scheme and Group Coloring. The user may make as many groups as desired, however the Group Coloring mode will color no more than 7 groups. All groups after the 7th, and any actuators not assigned to a custom group, will be grey in Group Coloring mode. A group's color will get darker as voltage increases, if there is no voltage on a group it will not be colored (See Figures 15 and 16).

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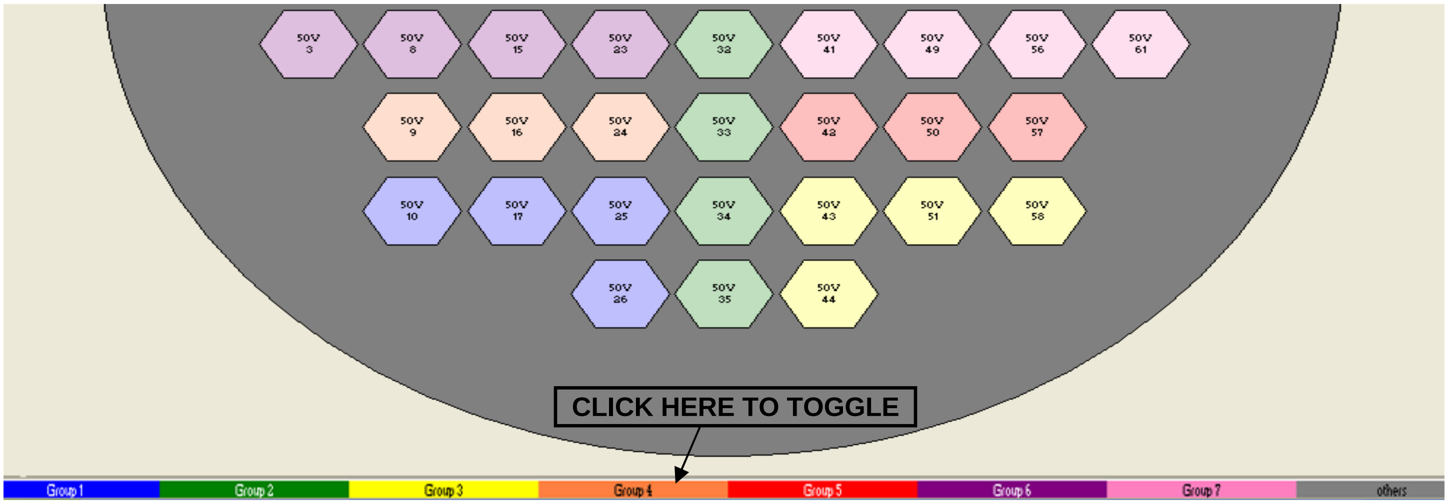

Figure 15: 25-61 Rectangular Pad Array Diagram In Group Coloring Mode. Voltage For All Groups Is 50v

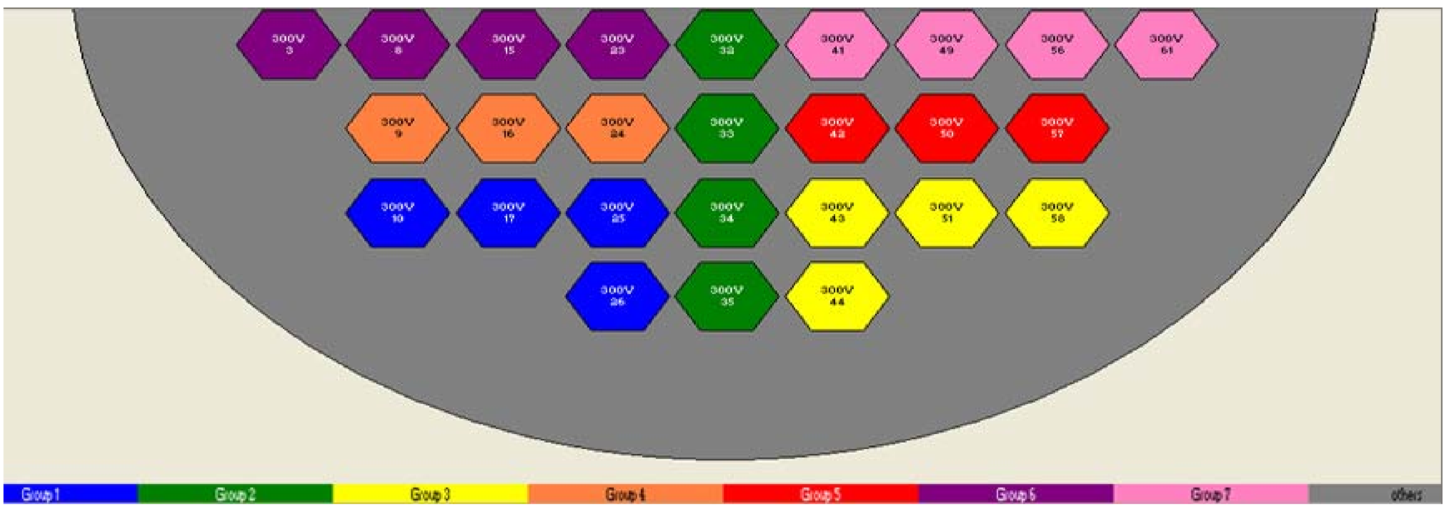

Figure 16: 25-61 Rectangular Pad Array Diagram In Group Coloring Mode. Voltage For All Group Is 300v.

3.9 Sequence

Under the **Sequence** tab (See Figure 17) are the controls for loading, saving and cycling through custom patterns as well as manipulating the Zernike patterns.

In the Zernike Window, there are three buttons and twelve slider bars.

- **Zero** sets all actuators to 0 volts.
- **Set** stores the current Zernike Aberration values and reset the Magnitudes to 0.
- **Restore** reloads the Zernike values last stored by clicking the **Set** button.

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The twelve Zernike aberrations included in HVDD are controlled with the slider bars or by typing values in the magnitude boxes. Sequence Control and Sequence Cycling allows the user to design custom patterns and repeat these patterns on the mirror.

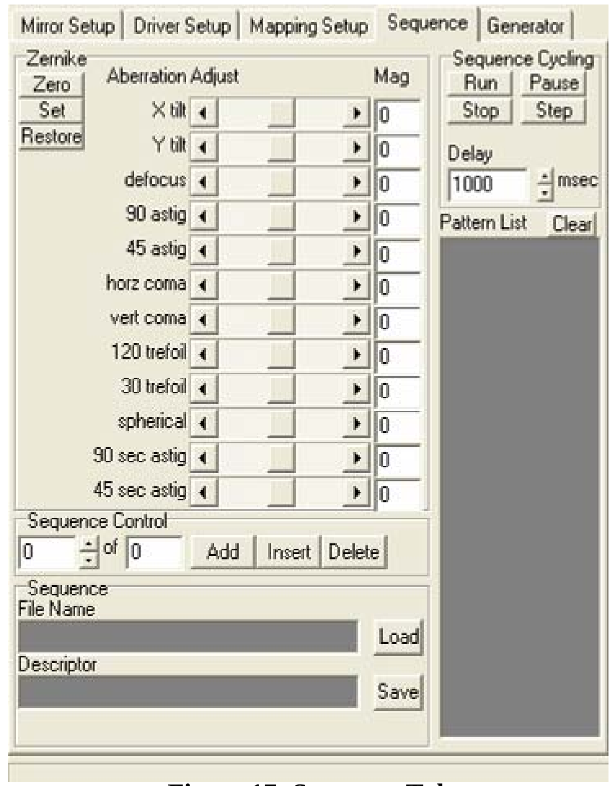

Figure 17: Sequence Tab

3.9.1 Pattern Sequencing

1) Click on the actuators in the Pad Array diagram and set them to the desired voltage level.
2) Click the **Add** button on the Sequence Control panel. A Pattern Create dialogue box appears.
3) Type in the pattern name or keep the default. No two patterns may have the same name.
4) Repeat steps 1 through 3 until all the patterns are configured.
5) Click the **Save** button under the Sequence Control box and enter a short sequence description. Click **OK** or hit Enter.
6) Type in the file name. Click **OK** or hit enter.

A previously saved Pattern Sequence may be loaded into HVDD.

1) Click **Load**
2) Enter the file name into the pop-up window
3) Click **Open** or press Enter.

Once the sequence groups are determined, the patterns are listed in the pattern list box.

1) Change the delay time for the sequencing delay in the **Delay** box.
2) Press **Run**.
3) The custom pattern continues until the user presses **Stop**

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3.10 Generator

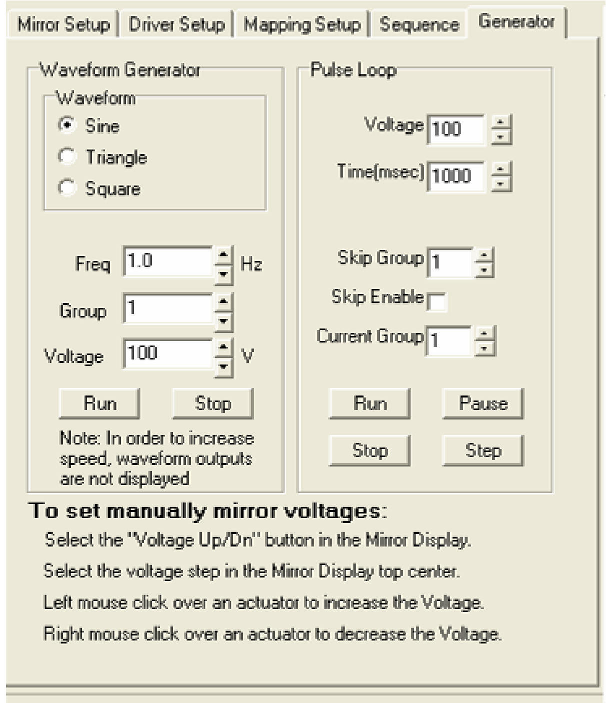

Figure 18: Generator Tab

Under the Generator tab are the functions for waveform generation and pulse looping.

Waveform Generator

HVDD provides three types of Waveforms: Sine, Triangle, and Square. All waveforms are at 50% duty cycle.

1) Select a waveform
2) Set the frequency using the **Freq** box.
3) Choose which group of actuators the waveform will output to using the **Group** box.
4) Set the output voltage of the waveform using the **Voltage** box.
5) Run initiates the waveform; a Green Light will turn on with “Running” displayed in the Voltage Limit area.
6) Stop turns off the waveform; a Red Light will turn on with “Stopped” displayed in the Voltage Limit area.

Pulse Loop

Pulse Loops allow the user to set each group to turn on for a fixed amount of time at a specified voltage. The default (1:1 Mapping) or user defined groups may be used with this function. Once the groups are defined, follow these steps.

1) Set the desired output voltage for the actuator groups in the **Voltage** box.
2) Set the pulse time using the **Time** box.
3) If a group is to be skipped, put that number in the **Skip Group** box then check **Skip Enable**. Only one group may be skipped.

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4) The **Current Group** box displays which group is active. If the number in this box is changed, the pulse loop will start with the next group.
5) Click **Run** for the loop to operate normally.
6) Clicking **Pause** holds the current group at the defined voltage. A yellow light with “Paused” displayed will appear in the Voltage Limit area. Un-pause the loop by clicking **Run** again.
7) Use the **Step** button to step through each group. The **Start** button can be clicked and the sequence will continue from the group displayed in the **Current Actuator** box.
8) Press **Stop** anytime to halt Pulse Loop execution.

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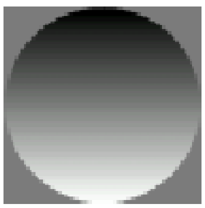
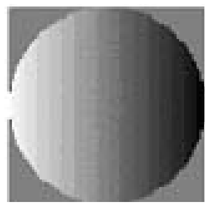
Appendix A – Zernike Polynomials

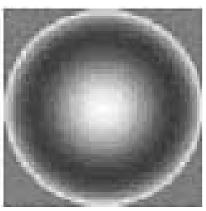
The Zernike polynomials are a set of functions that are orthogonal over the unit circle. They are useful for describing the shape of an aberrated wavefront in an optical system. Their usefulness derives from the fact that the most commonly encountered aberrations or deformations in real optical systems are commonly represented by lower-order polynomials in the Zernike Series. Several different normalization and numbering schemes for these polynomials are in common use. We have elected to use the following numbering in the HVDD software:



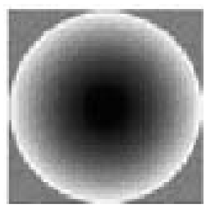
Zernike 1,-1 – X-axis Tilt



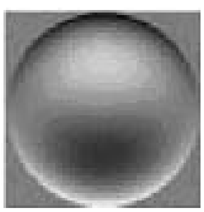
Zernike 1,1 – Y-axis Tilt



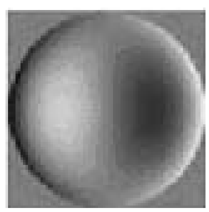
4,0 – Spherical Aberration



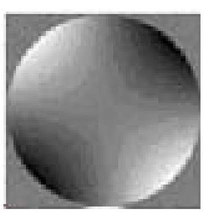
2,0 – Focus



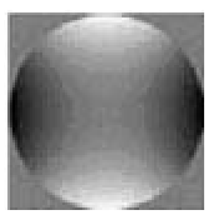
3,-1 – Vertical Coma



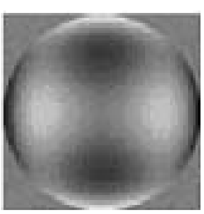
3,1 – Horizontal Coma



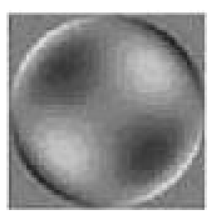
2,-2 – 45° Astigmatism



2,2 – 90° Astigmatism



4,2 – Secondary Astigmatism



4,-2 – 45° Secondary Astigmatism

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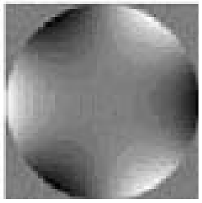
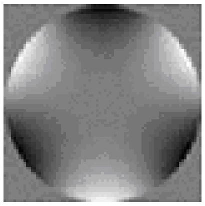
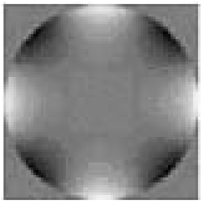


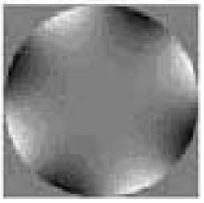
3,3 – Triangular Astigmatism (Trefoil)



3,-3 – 30° Triangular Astigmatism(Trefoil)



4,4 – Quadrafoil



4,-4 – 22 ½° Quadrafoil

A table showing the Zernikes used by the HVDD™ software and the corresponding Zernike numbers as shown above is presented here.

Zernike in software	Zernike Number (n,m)	Name
1	2,0	Focus
2	2,2	90° Astigmatism
3	2,-2	45° Astigmatism
4	3,-1	Vertical Coma
5	4,0	Spherical Aberration
6	3,-3	30° Triangular Astigmatism
7	3,1	Horizontal Coma
8	3,3	Triangular Astigmatism
9	4,-2	45° Secondary Astigmatism
10	4,2	Secondary Astigmatism

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Appendix B – Safety and Handling of Drive and Deformable Mirror

HVDD applies voltage to the driver **immediately** after selection. Use high voltage safety procedures with this hardware and software.

1) Do not adjust output cables while there is power to the drive.
2) Do not allow the unused output cables of the drive to short to ground or to one another.
3) All unused output cables should be protected when not in use. AgilOptics recommends the use of Kapton® tape to protect the cables.
4) Never touch output cable ends while circuit is live. **Possible 300v shock to user!**
5) Always disconnect USB cable and power to the drive before moving any output cables.

Deformable mirrors are very fragile and proper handling is extremely important. The following are suggestions to extend the life of your DM.

1) Never touch the membrane with a finger or foreign object.
2) Do not use the fender-washer-Mylar-tape cover as a working cover. This is used as gross protection for shipment only.
3) Use a plastic box for storage and put away after use. Some users keep the mirror in their mounts and cover with a plastic bag.
4) Over voltage on a mirror WITHOUT ASD (Anti-SnapDown) is extremely destructive.
5) Dust and particles can also rupture the membrane if they are between the membrane and the actuators. Store in a plastic container with the seal taped shut for extended periods.
6) Set all actuator voltages to ZERO (0) before turning off the driver.

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