HVDD Software Instruction Manual

Version 6.0

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1 Introduction to HVDD 6.0

1.1 Updated Software

HVDD is an acronym for **H**igh **V**oltage **D**igital **D**river.

HVDD 6.0 is the base software for controlling any of AgilOptics' deformable mirrors. HVDD can interface with all of AgilOptics' current deformable mirror drivers such as the D40DI or the D64USB. After the software is installed, the PC communicates with the driver over parallel or USB cable.

Updates include

- USB 2.0 Drivers
- Bug fixes.

HVDD allows the user to selectively control individual mirror actuators or place Zernike Aberration patterns onto the deformable mirror (DM) using a graphical user interface. A set of slide bars allows the user to scale these distortions up to the limits of the voltage settings. HVDD 6.0 is designed for open-loop control systems. No feedback to the software is needed.

IMPORTANT:
Voltages selected using HVDD are IMMEDIATELY sent to the mirror if one is connected. Safe high voltage operation should always be considered when using this hardware and software. See Appendix C - Safety and Handling of Deformable Mirrors for tips on proper operation and handling of deformable mirrors and high voltage drivers.

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1.2 Deformable Mirrors

The figure below 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.

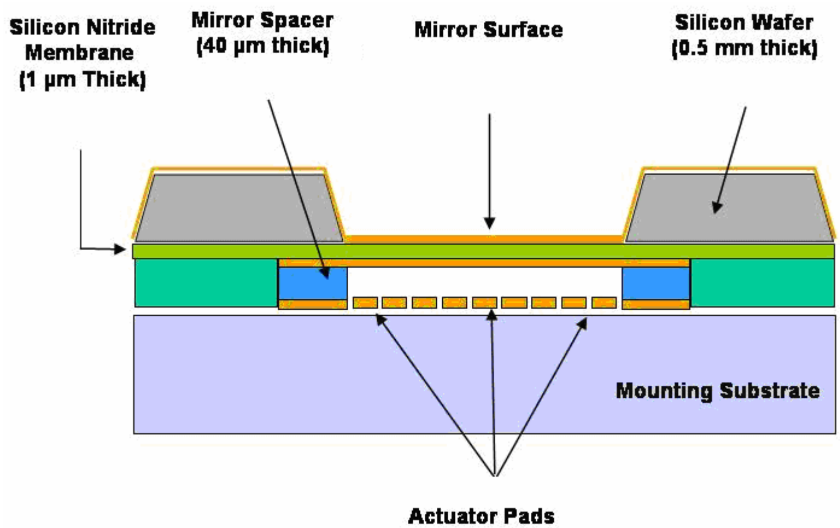

Figure 1 Cross section of an AgilOptics' Deformable Mirror

1.2.1 What Are Deformable Mirrors?

Adaptive optics is a term for optical elements that can change their optical properties in response to control signals. Deformable mirrors (DM) are adaptive optics with 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 removes these "wrinkles" in the wavefront to clarify the image and improve resolution.

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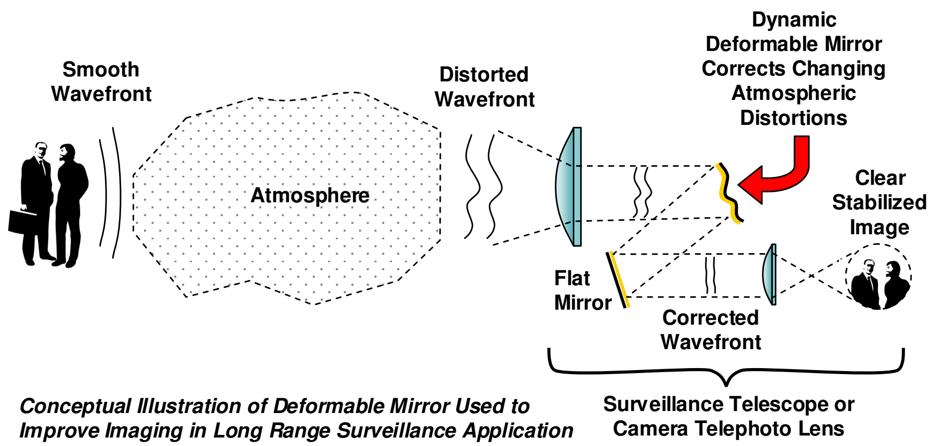

Figure 2 Atmospheric Aberration Correction

Imperfections in the laser beam significantly reduce the ability to keep the illuminated circle as small as possible, or 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 laser beams desirable in the first place. By replacing one of the fixed mirrors within the laser cavity, an even better improvement in performance is 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 potential 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.

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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 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.

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2 HVDD 6.0 Quick Start Tutorial

2.1 Installing a DM into your Optics setup

1) Install the DM into an optical mount.
2) Connect the driver input to a PC.
3) Connect the driver output to the DM. An interface box may be needed depending on the mirror and the driver.
4) Connect a power cord to the driver and plug the system in.
5) Do not turn on the driver until software is started.

2.2 Starting the Software

For this series of step-by-step instructions to work, an AgilOptics' deformable mirror and driver must be installed into your optical system.

1) Double-click on the HVDD link to start HVDD 6.0.
2) Double-click on the mirror type you have installed from the list displayed in the Mirror Types box. The Mirror Setup Tab will be active when the software begins.
3) Double-click on the driver unit that is connected to the mirror. The Driver Setup tab will activate once a mirror is chosen.
4) Turn on the driver.
5) Click on the Sequence tab.
6) Click once on the Group Color bar, below the Pad Array Diagram. This will turn on the Voltage gradient color scheme.
7) Adjust any of the slider bars in the Aberration Adjust list. The Pad Array Diagram will change colors indicating voltage change.
8) Congratulations! You are now in control of an AgilOptics' Deformable Mirror.

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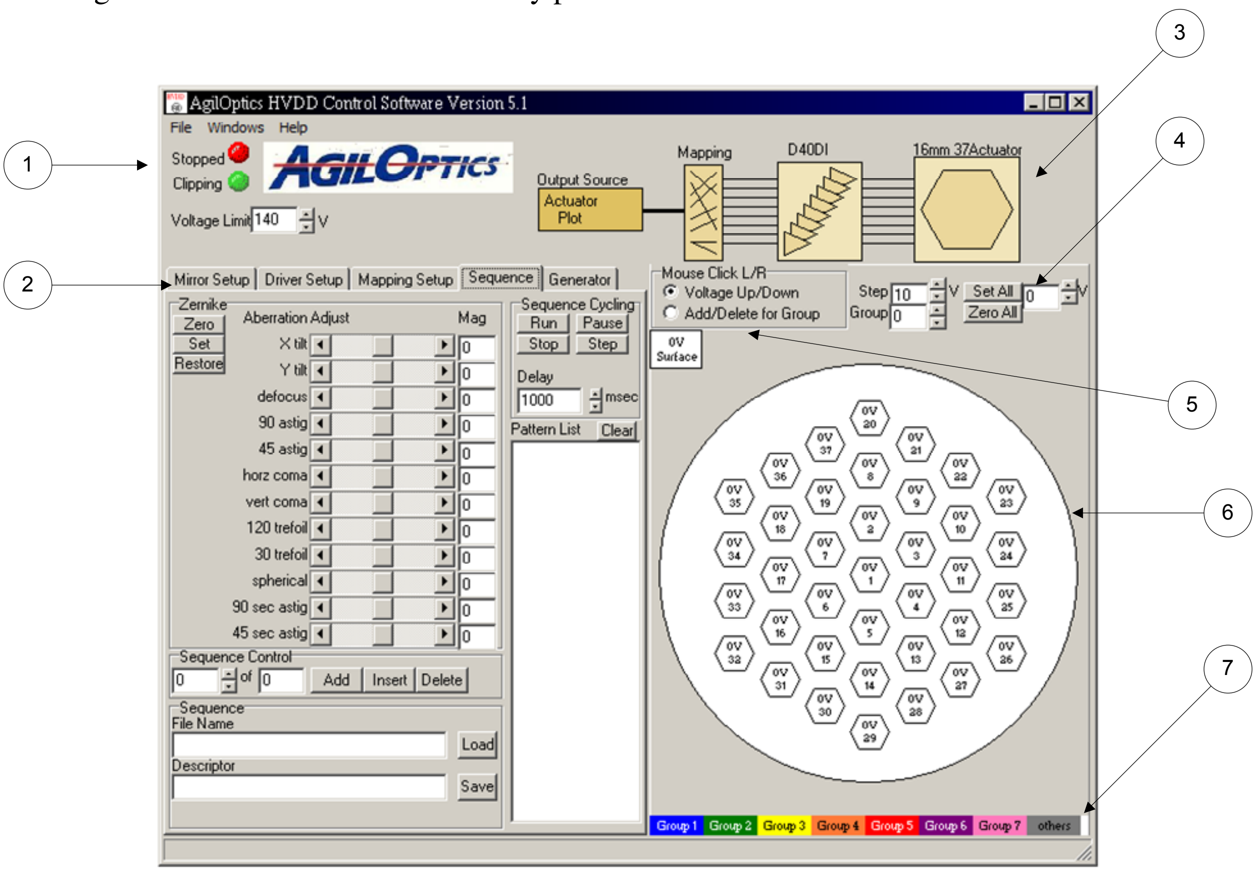
3 Advanced Users Guide

3.1 Learning the New Interface

The image below shows the location of key points on the HVDD 6.0 user interface.



①. Voltage Limit Area
②. Setup and Operating Tabs
③. Current Configuration Diagram
④. Actuator Control
⑤. Pad Array Diagram Settings
⑥. Pad Array Diagram
⑦. Group Visualization Bar

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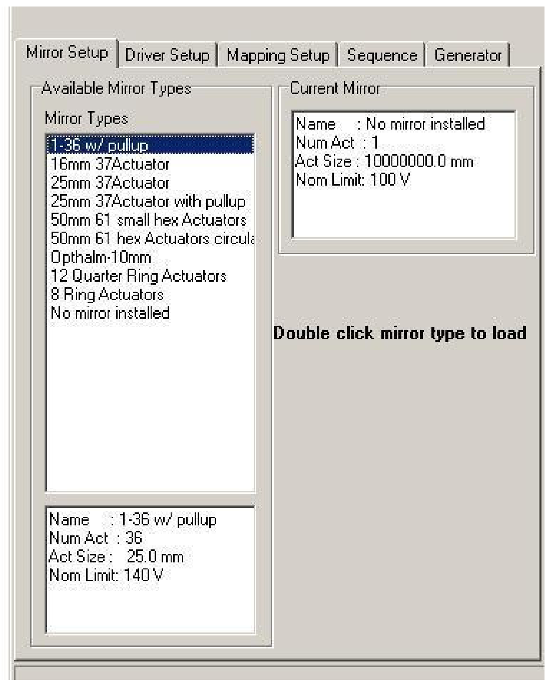
3.2 Voltage Limit

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 then the green lower light will 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" will be displayed to the left of the light.

3.3 Setup and Operating Tabs



3.3.1 Mirror Setup

- The Mirror Setup tab is active upon starting the program.
- Single-click on a mirror listed in the Mirror Types to display information about the mirror in the box below the list of Mirror Types.
- Double-Clicking on a mirror will update software to reflect your choice and the Current Mirror box will display the chosen mirror.

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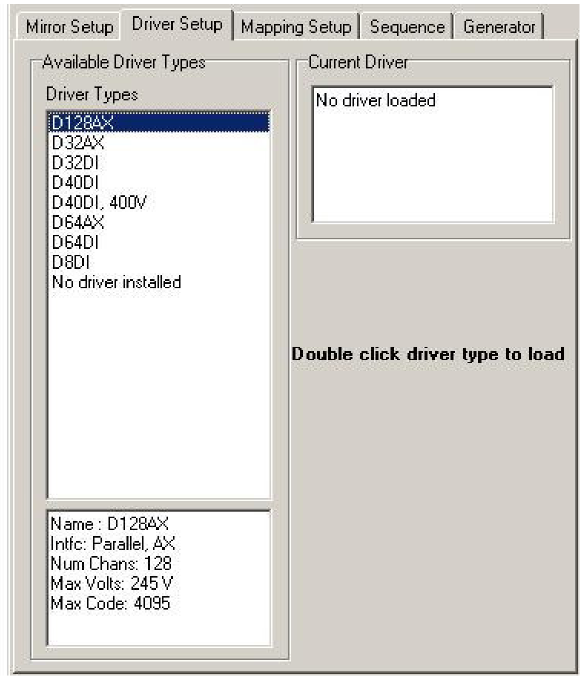
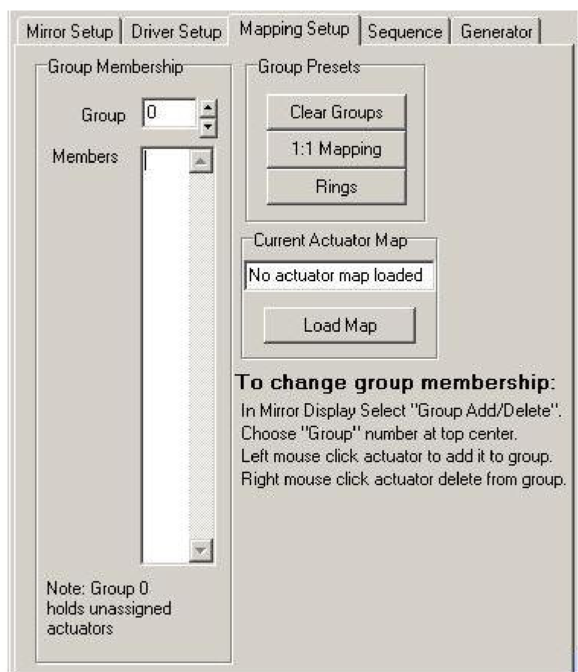
3.3.2 Driver Setup



- Use the Driver Setup tab to choose which AgilOptics' driver is connected to the mirror.
- Single-Clicking on a driver listed in the Available Driver Types box will display information about that driver in the box below the driver listing.
- Double-Clicking on a driver will update the software and the driver information will be displayed in the Current Driver box.

3.3.3 Mapping Setup



- The Mapping Setup tab allows the user to group actuators into control groups. Each control group will have the same voltage and are controlled as if they are one actuator in the other parts of the program.
- Clicking any one of the grouped actuators on the Pad Array Diagram will change the voltage to be 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.

<u>Group Membership window</u>
This window displays the current groups. Typing a number or clicking on the arrows next to the Group box will show what actuators are associated with a given Group.

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Group Presets

- *1:1 Mapping* returns the control map to the default state with one actuator per control channel.
- *Rings* makes each set of concentric rings in an actuator array a single control group.
- *Clear Groups* removes all current group mappings.

Current Actuator Map

For HVDD to work a data file is loaded 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 running behind the software. 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.

3.3.3.1 Actuator Grouping

Follow the steps here to create custom actuator groupings. By default, all actuators are set to 1:1 Mapping.

1) Click the Clear Groups button.
2) Select Add/Delete for Group radio button
3) Select the group number in the Group Membership box.
4) Select the number of actuator groups by incrementting the group number in the group membership box.
5) Left Click on an actuator displayed in the Pad Array Diagram to add that actuator to the current group. The actuator number will be displayed in the Membership box.
6) 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 actuators will be set to group 0.
- The same procedures can be used on the Mirror Voltage Plot using the Group box.
- Actuators may belong to only ONE group at a time.

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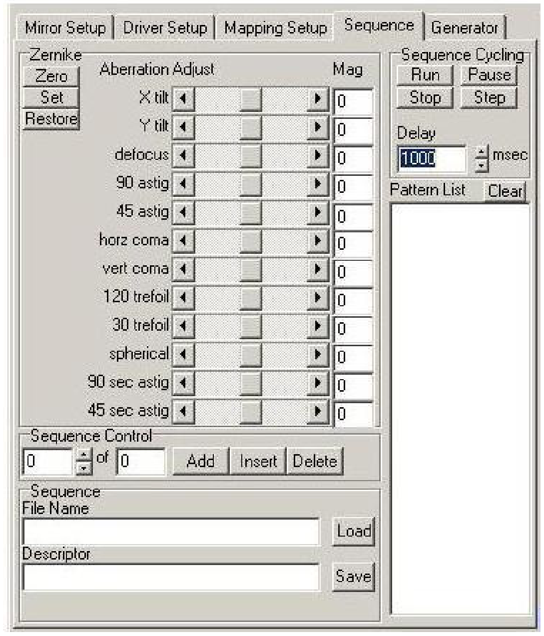
3.3.4 Sequence



Under the Sequence tab are the controls for manipulating Zernike aberrations, loading, saving and cycling through patterns.

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

- *Zero* will set all mirror actuators to 0 volts.
- *Set* will store the current Zernike Aberration values and reset the Magnitudes to 0.
- *Restore* will reload the Zernike values last stored by clicking the *Set* button.

The twelve Zernike aberrations that a DM can compensate for are controlled with the slider bars or by typing values in the magnitude boxes.

Sequence Control and Sequence Cycling allow the user to design custom patterns and repeat these patterns on the face of the mirror.

3.3.4.1 Pattern Sequencing

1) Click on the actuators in the pad array diagram and set them to you desired voltage level.
2) Click the ADD button on the Sequence Control panel. A Pattern Create Pop-up appears.
3) Type in the pattern name or keep the default.
4) Repeat steps 1 through 3 until all the patterns have been 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.

Operating a sequence on a mirror is very simple. Once the sequence groups have been 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.

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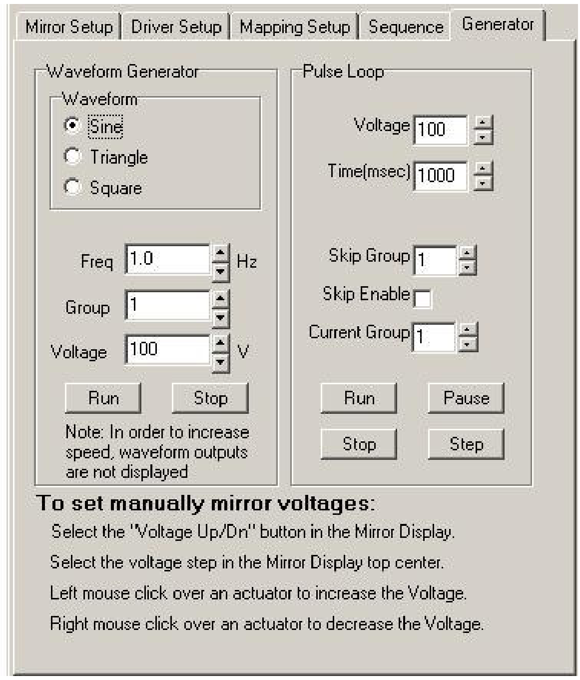
3.3.5 Generator



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

<u>Waveform Generator</u>

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

1) Select a waveforms
2) Set the frequency using the Freq box.
3) Choose which group of actuators the wave form 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.

<u>Pulse Loop</u>

Pulse Loops allow the user to set each group to turn on for a fixed amount of time at a specified voltage. Before Pulse Loop can operate, the user must define the actuator groupings under the Mapping Setup tab.

Once the groups are defined, follow these steps.

1) Set the voltage that should be output to each group in the Voltage box.
2) Set the “on” pulse time using the Time box.
3) If a group is to be skipped, but that number in the Skip Group box then check Skip Enable. Only one group may be skipped. This group is usually the mirror face.
4) The Current Group box displays which group is active. If you change the number in this box, the pulse loop will start at the defined actuator.
5) Click Run for the loop to operate normally.
6) Clicking Pause will hold the current actuator 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 actuator displayed in the Current Actuator box.
8) Press Stop anytime to halt Pulse Loop execution.

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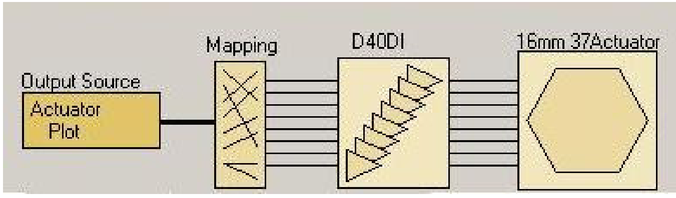
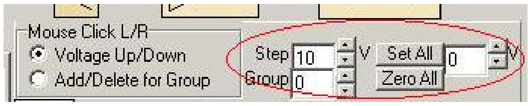
3.4 Current Configuration Diagram

The Current Configuration Diagram 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 will launch the Mirror Voltage Plot window. The Mirror Voltage Plot displays and interacts exactly the same way as the Pad Array Diagram.

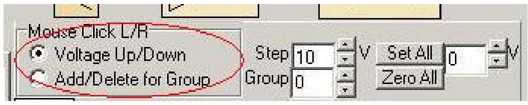
3.5 Actuator Control



This area of the user interface sets how clicking on the Pad Array Diagram will affect the mirror.

- *Step* will set the voltage change, both up and down, when clicking on the Pad Array Diagram.
- *Set All* will output the voltage specified in the box to all the actuators on the mirror EXCEPT for the mirror face.
- *Zero All* will set all pads to 0 volts.
- *Group* is used to add actuators to a defined group. This button is used in conjunction with the Pad Array Diagram Settings.

3.6 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.

- *Voltage Up/Down* will set clicking on the Pad Array Diagram to change actuator voltages.
- *Add/Delete for Group* will set clicking on the Pad Array Diagram to group editing.

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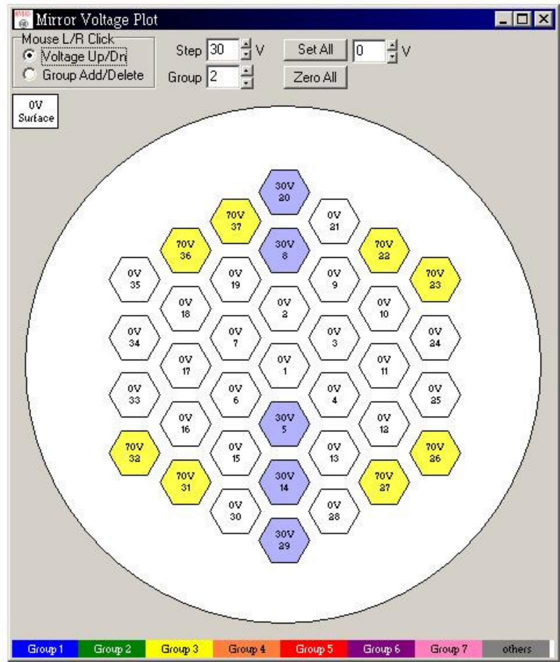
3.7 Pad Array Diagram

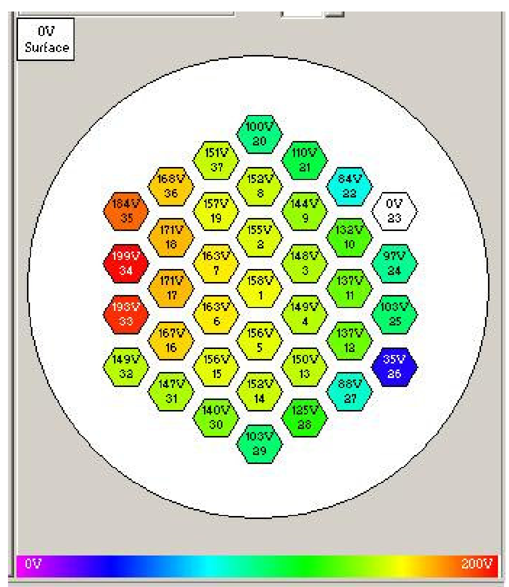
This area of the user interface is where the most work will be done.

Click on any of the displayed actuators to turn the voltages up or down or add or remove actuators to a group.



3.8 Group Visualization Bar

The colored bar below the Pad Array Diagram shows the group colors as they appear on the actuators. Clicking on this bar will switch the mode between Voltage Gradient Color Scheme and Group Coloring.



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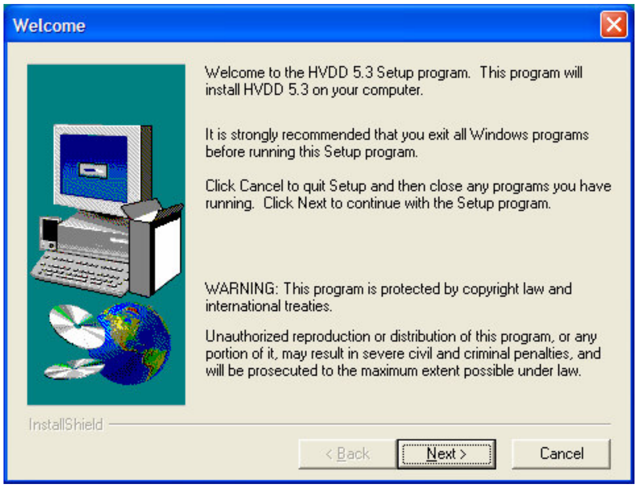
4 Appendix A – Software Installation

The installation files for HVDD 6.0 are included on a CD-Rom or may be downloaded off the Web at www.agiloptics.com.



1. Locate the file **Setup.exe** on the CD-Rom or within the HVDD 6.0 folder.
2. Click on **Setup.exe** to begin installation.
3. Follow the instructions shown on InstallShield.
4. Click on HVDD icon on the desktop or find the HVDD link on the Start Menu to start the program. See **Figure 2**.

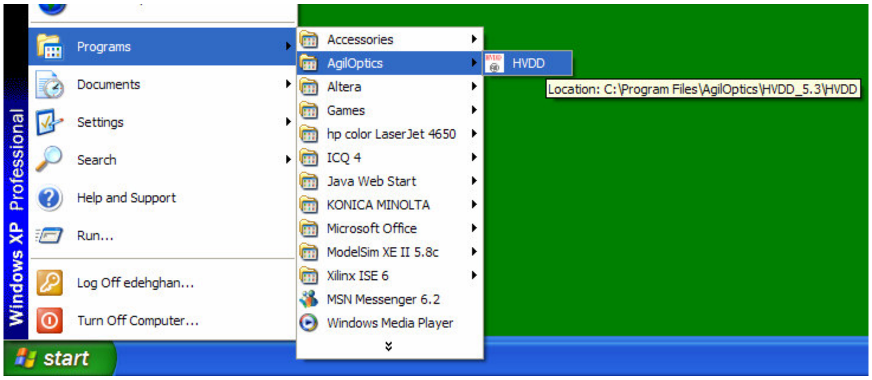


Figure 4 Location of HVDD on Start Menu

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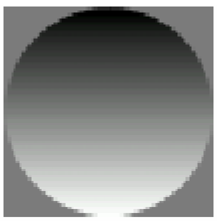
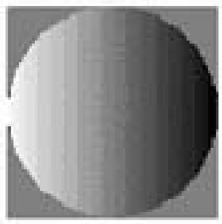
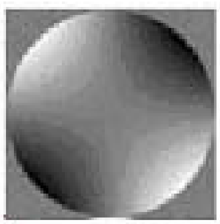
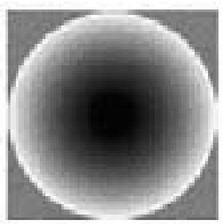
5 Appendix B - Zernike

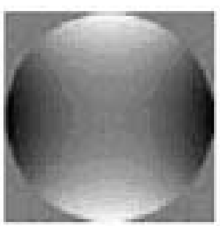
The Zernike polynomials are a set of functions that are orthogonal over the unit circle. They are useful for describing the shape of an aberrated wavefront in an optical system. Their usefulness derives from the fact that the most commonly encountered aberrations or deformations in real optical systems are, for the most part, 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:

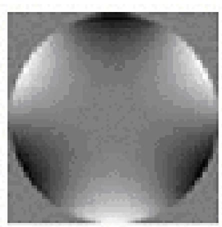

Zernike 1,-1 – X-axis Tilt

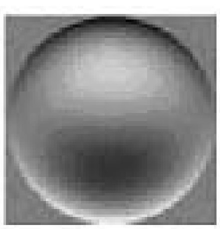

Zernike 1,1 – Y-axis Tilt

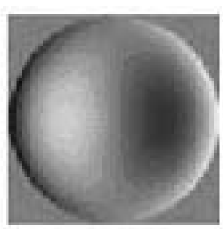

2,-2 - 45° Astigmatism


2,0 - Focus


2,2 - 90° Astigmatism


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


3,-1 – Vertical Coma


3,1 – Horizontal Coma

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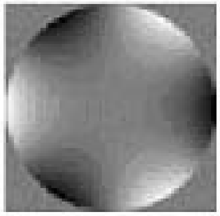
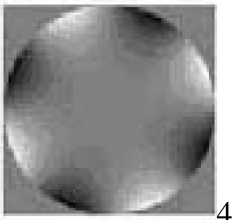
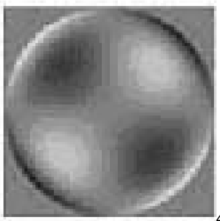
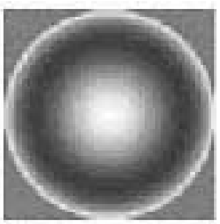
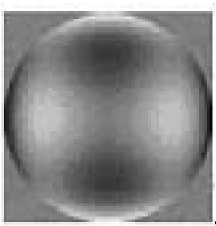
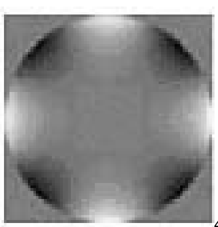

3,3 –Triangular Astigmatism (Trefoil)


4,-4 -- 22 ½ ° Quadrafoil


4,-2 –45° Secondary Astigmatism


4,0 -- Spherical Aberration


4,2 –Secondary Astig.


4,4 -- Quadrafoil

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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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6 Appendix C - Safety and Handling of Deformable Mirrors

Handling tips from AgilOptics!!

Deformable mirrors are very fragile and proper handling is extremely important. The following are some suggestions on proper handling.

1) Use extreme care that nothing touches the membrane; this will cause it to rupture.

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) Make sure all voltage to actuators is removed by using the “zero all” button on controlling before turning off the driver.

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