

8783 GuideStar™ II Controller



User's Manual



EU Declaration of Conformity

We declare that the accompanying product, identified with the **CE** mark, complies with requirements of the Electromagnetic Compatibility Directive, 2004/108/EC and the Low Voltage Directive 2006/95/EC.

Model Numbers: 8783

CE mark affixed: 2012

Type of Equipment: Electrical equipment for measurement, control and laboratory use in industrial locations.

Manufacturer:

Newport Corporation
1791 Deere Avenue
Irvine, CA 92606

Standards Applied:

- Compliance was demonstrated to the following standards to the extent applicable:
- BS EN61326-1: 2006 “Electrical equipment for measurement, control and laboratory use – EMC requirements” for use in a controlled electromagnetic environment.
- This equipment meets the CISPR 11:2009+A1 Class A Group 1 radiated and conducted emission limits.
- BS EN 61010-1:2001, 2nd Edition “Safety requirements for electrical equipment for measurement, control and laboratory use”.



Dominique Devidal Quality Director Zone Industrielle
45340 Beaune-la-Rolande, France

Warranty

New Focus warrants that this product will be free from defects in material and workmanship and will comply with Newport's published specifications at the time of sale for a period of one year from date of shipment. If found to be defective during the warranty period, the product will either be repaired or replaced at Newport's option.

To exercise this warranty, write or call your local Newport office or representative, or contact Newport headquarters in Irvine, California. You will be given prompt assistance and return instructions. Send the product, freight prepaid, to the indicated service facility. Repairs will be made and the instrument returned freight prepaid. Repaired products are warranted for the remainder of the original warranty period or 90 days, whichever first occurs.

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First printing 2012

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Part No. 90038357 Rev A

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Service Information

This section contains information regarding factory service for the source. The user should not attempt any maintenance or service of the system or optional equipment beyond the procedures outlined in this manual. Any problem that cannot be resolved should be referred to New Focus.

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Newport Corporation Calling Procedure

If there are any defects in material or workmanship or a failure to meet specifications, promptly notify Newport's Returns Department by calling 1-800-222-6440 or by visiting our website at www.newport.com/returns within the warranty period to obtain a **Return Material Authorization Number (RMA#)**. Return the product to Newport Corporation, freight prepaid, clearly marked with the RMA# and we will either repair or replace it at our discretion. Newport is not responsible for damage occurring in transit and is not obligated to accept products returned without an RMA#.

E-mail: rma.service@newport.com

- When calling Newport Corporation, please provide the customer care representative with the following information:
- Your Contact Information
- Serial number or original order number
- Description of problem (i.e., hardware or software)
- To help our Technical Support Representatives diagnose your problem, please note the following conditions:
- Is the system used for manufacturing or research and development?
- What was the state of the system right before the problem?
- Have you seen this problem before? If so, how often?
- Can the system continue to operate with this problem? Or is the system non- operational?
- Can you identify anything that was different before this problem occurred?

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1 Introduction

1.1 Summary of GuideStar™ II System

The GuideStar II laser stabilization system guarantees critical alignment of complex laser systems by compensating beam pointing and position drift. The system is based on Picomotor™ actuated mirrors which provide high-precision control with outstanding intrinsic stability. Two miniature cameras provide complete position, pointing, and profile information, while dedicated software implements a user-friendly, intelligent control algorithm that keeps the beam's four degrees of freedom precisely locked. The position data is fed back to the mirror using our patented control algorithm (US Patent # 7,528,364 Optical Beam Steering and Sampling Apparatus and Method, 2009), the only technique that completely corrects the laser beam position in both X and Y and the beam rotation about both X and Y.

The system is anchored by the small GuideStar II Model 8783 controller which serves as a USB hub for communication with the cameras and also serves as a multiplexed Picomotor driver to generate drive signals for the four motors.

The controller connects to the user's host computer via USB. And the host computer runs the GuideStar II software which is user-friendly and conveniently permits full beam profiles and beam position data which can be tracked, stored, and analyzed. An easy set-up menu guides new users through the installation. Simple settings menus allow complete control of a wide range of camera and beam stabilization parameters including: 1000:1 dynamic camera exposure time, loop gain to optimize performance of the control loop, and complete control of target size and location for each camera.

Designed for accuracy, reliability, and ease-of-use, the GuideStar™ II System is the answer to laser beam drift correction for the most demanding laser applications.

2 Safety Precautions

2.1 Definitions and Symbols

The following terms and symbols are used in this documentation and appear on the Model 8783 GuideStar II controller where safety-related issues occur.

2.1.1 General Warning or Caution



Figure 1. General Warning or Caution Symbol

The Exclamation Symbol in the figure above appears on the product and in Warning and Caution tables throughout this document. This symbol designates that documentation needs to be consulted to determine the nature of a potential hazard, and any actions that have to be taken.

2.1.2 Electric Shock



Figure 2. Electrical Shock Symbol

The Electrical Shock Symbol in the figure above appears throughout this manual. This symbol indicates a hazard arising from dangerous voltage. Any mishandling could result in irreparable damage to the equipment, and personal injury or death.

2.1.3 European Union CE Mark



Figure 3. CE Mark

The presence of the CE Mark on Newport Corporation equipment means that this instrument has been designed, tested and certified compliant to all applicable European Union (CE) regulations and recommendations.

2.1.4 Alternating Voltage Symbol



Figure 4. Alternating Voltage Symbol

This international symbol implies an alternating voltage or current.

2.1.5 USB



Figure 5. USB Symbol

The symbol in the figure above identifies the USB connector location on the Model 8783 Controller.

2.1.6 Frame or Chassis

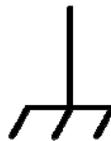


Figure 6. Frame or Chassis Terminal Symbol

The symbol in the figure above appears on the Model 8783 Controller. This symbol identifies the frame or chassis terminal.

2.1.7 Waste Electrical and Electronic Equipment (WEEE)



Figure 7. WEEE Directive Symbol

This symbol on the product or on its packaging indicates that this product must not be disposed with regular waste. Instead, it is the user responsibility to dispose of waste equipment according to the local laws. The separate collection and recycling of the waste equipment at the time of disposal will help to conserve natural resources and ensure that it is recycled in a manner that protects human health and the environment. For information about where the user can drop off the waste equipment for recycling, please contact your local Newport Corporation representative.

2.1.8 Control of Hazardous Substances

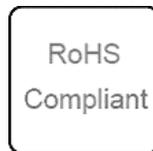


Figure 8. RoHS Compliant Symbol

This label indicates the products comply with the EU Directive 2002/95/EC that restricts the content of six hazardous chemicals.

2.2 Warnings and Cautions

2.2.1 General Warnings

Observe these general warnings when operating or servicing this equipment:

- Heed all warnings on the unit and in the operating instructions.
- Do not use this equipment in or near water.
- This equipment is grounded through the grounding conductor of the power cord.
- Route power cords and other cables so that they are not likely to be damaged.
- Disconnect power before cleaning the equipment. Do not use liquid or aerosol cleaners; use only a damp lint-free cloth.
- Lockout all electrical power sources before servicing the equipment.
- To avoid fire hazard, use only the specified fuse(s) with the correct type number, voltage and current ratings as referenced in the appropriate locations in the service instructions or on the equipment. Only qualified service personnel should replace fuses.
- To avoid explosion, do not operate this equipment in an explosive atmosphere.
- Qualified service personnel should perform safety checks after any service.

2.2.2 General Cautions

Observe these cautions when operating this equipment:

- If this equipment is used in a manner not specified in this manual, the protection provided by this equipment may be impaired.
- Do not block ventilation openings.
- Do not position this product in such a manner that would make it difficult to disconnect the power cord.
- Use only the specified replacement parts.
- Follow precautions for static sensitive devices when handling this equipment.
- This product should only be powered as described in the manual.
- There are no user-serviceable parts inside the Model 8783 GuideStar II controller.
- Adhere to good laser safety practices when using this equipment.

2.2.3 Summary of Warnings and Cautions

The following are definitions of the Warnings, Cautions and Notes that are used throughout this manual to call your attention to important information regarding your safety, the safety and preservation of your equipment, or an important tip. The following general warning and cautions are applicable to this instrument:

	<i>Before operating the Model 8783 GuideStar II controller, please read and understand all of Section 2.</i>
	<i>Do not attempt to operate this equipment if there is evidence of shipping damage or you suspect the unit is damaged. Damaged equipment may present additional hazards to you. Contact Newport technical support for advice before attempting to operate damaged equipment.</i>
	<i>Before cleaning the enclosure of the Model 8783 GuideStar II controller, the AC power cord must be disconnected from the wall socket.</i>
	<i>To avoid electric shock, connect the instrument to properly earth-grounded, 3-pronged receptacles only. Failure to observe this precaution can result in severe injury/death.</i>
	<i>There are no user serviceable parts inside the Model 8783 Guidestar II controller. Work performed by persons not authorized by Newport Corporation will void the warranty.</i>
	<i>If this equipment is used in a manner not specified in this manual, the protection provided by this equipment may be impaired.</i>

2.2.4 Additional power supply warnings

This product is equipped with a three prong plug. For proper operation and your protection this plug should not be modified and must be plugged directly into a properly grounded three prong receptacle.

This product is not provided with a power switch. Do not block access to the power connector in case emergency shutdown is required.

Voltages of up to 130V are accessible inside the driver chassis, mounts, and Picomotors. Although protection circuits are included, do not operate the units with the driver or mount covers removed. If the wire of a mount or Picomotor is frayed, discontinue use and return item for repair.

3 Getting Started

3.1 Unpacking and Handling

It is recommended that the Model 8783 GuideStar II controller be unpacked carefully in a lab environment; small parts are included with the instrument. Inspect the box carefully for loose parts. You are advised to save the packaging material in case you need to ship your equipment in the future.

3.2 Inspection for Damage

The Model 8783 GuideStar II controller is carefully packaged at the factory to minimize the possibility of damage during shipping. Inspect the box for external signs of damage or mishandling. Inspect the contents for damage. If there is visible damage to the instrument upon receipt, inform the shipping company and New Focus immediately. Carefully open the box and save the shipping material for later use.

3.3 Parts List

The following is a list of parts included with the Model 8783 GuideStar II controller:

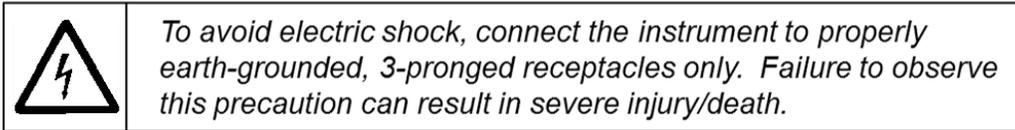
- 8783 GuideStar II controller
- CD with Software Drivers and Utilities, User's Manual, Start Up Guide.
- Power adaptor and power cord.
- USB cable for connecting to computer. If you are missing any parts or have questions about the parts you have received, please contact New Focus.

3.4 Choosing and Preparing a Suitable Work Surface

The GuideStar II may be placed on any reasonably firm table or bench during operation.

3.5 Electrical Requirements

Before attempting to power up the unit for the first time, the following precautions must be followed:



- Have a qualified electrician verify the wall socket that will be used is properly polarized and properly grounded.
- Provide adequate distance between the Models 8783 GuideStar II Controller and adjacent walls for ventilation purposes. Do not let any other equipment blow hot air towards the unit.

3.6 Computer requirements

Software:

Windows 7 – 32 bit, 64 bit

Windows XP – 32 bit only

Processor:

AMD DUAL CORE, AMD QUAD CORE

Intel Pentium Dual Core, Intel Pentium Quad Core, Intel Pentium Core (i3 , i5 , i7)

RAM 4GB minimum

HDD 160GB minimum

DVD player

Screen resolution: 1920x1080 minimum

Monitor: HD 1920x1080 resolution minimum

4 System Operation

4.1 System Overview

GuideStar II is a closed-loop beam stabilization system in which cameras measure beam position at two points along the beam path, while two preceding mirrors actuated by Picomotors keep these two positions steady. The centroid information from each camera is processed and fed back to the X and Y control of each mirror mount in a generalized manner via a 16-element array (called the “Motion Matrix”). This approach accounts for all direct- and cross- couplings between the centroid position and the mirror axes, allowing for nominally perfect control of the beam with arbitrary optical systems. An automated calibration routine provides the needed stimulus to each motor to determine the Motion Matrix values.

The control loop functions by making adjustments to the mirrors only when the beam has drifted out of a user-defined target area on one or both of the camera sensors. When this happens, the beam is moved back inside the target area on both sensors. To provide control over how often the beam is moved, an Inner Target and an Outer Target are defined for the sensors. When the beam drifts outside of one or both of the Outer Targets, it is moved back inside the smaller Inner Target on both sensors. Then it is not moved again until it drifts outside of one or both of the Outer Targets. Suitable choice of the target sizes can result in relatively infrequent motor activity to maintain beam pointing and position within a user-defined range. Thus the beam can be left largely unperturbed.

Dynamic performance of the control loop is determined by several things. Two settings in particular allow one to control the dynamic behavior – the *Loop Gain* and *Frames to Average Over*. These provide the flexibility to optimize the loop response.

The Model 8784 cameras are shipped with an installed lens and neutral density filters. The lens provides beam size reduction, allowing ~1-cm beams to be used with the 5.3 mm sensors. The cameras’ OD-1,-2, and -4 filters provide coarse optical attenuation, while the exposure time setting of the cameras allows for fine exposure control over a range of roughly 1 – 1000 ms.

In addition, operation with low (<500 Hz) repetition rate lasers is possible with the Model 8783-T Trigger Kit.

4.2 System set up

The Quick Start Guide contains information to set up the system. Please refer to the quick start guide to install software, configure the cameras, and connect components with the included cables. Additional details on hardware set up and software operation are found below.

4.3 Hardware set up

4.3.1 Beam Pick-offs and Optical Power

The power required for the cameras is low, so it is recommend that the leakage through HR mirrors with polished backsides be used as beam “pickoffs.” Other options include reflections off AR surfaces or uncoated beam-splitters in the beam. The saturation power of the cameras is shown in Figure 3.2a. If beam size and exposure time are accounted for, this figure can be used to choose appropriate pick-offs and attenuation for the beam. Fine tuning of power is accomplished via the exposure time so as to maximize dynamic range.

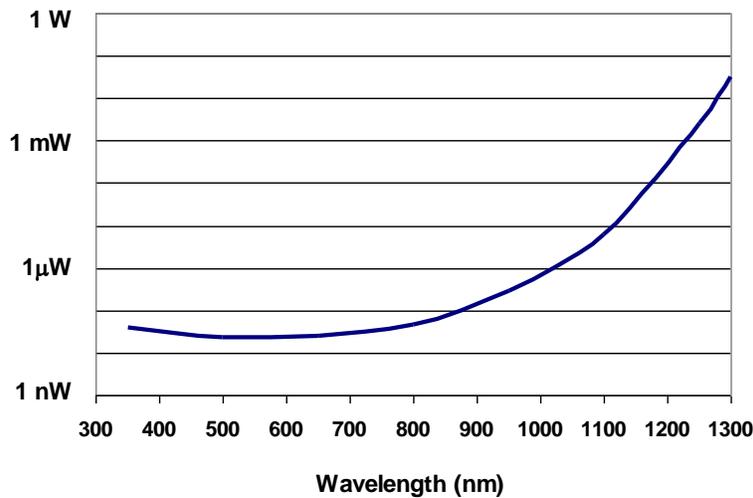


Figure 9. Approximate saturation power of the cameras with a 10-ms exposure time and a 2-mm beam diameter. Exposure time can range from 1 to 980 ms.

4.3.2 Optical Layout

The physical layout of the two cameras and two motorized mirror mounts may affect the performance of the GuideStar II System. As a general guideline, the separation between the mirrors and the separation between the cameras should be large and comparable, while the separation between Mirror 2 and Camera 1 should be much shorter, as short as conveniently possible (see Figure 3.2b).

Typical values might be 50 cm between mirrors, 50 cm between cameras, and 10 cm between Mirror 2 and Camera 1.

Note that the system can tolerate a wide range of deviation from these guidelines. In general, however, a larger spacing between cameras will allow for tighter pointing control, since the maximum pointing drift under closed-loop operation will be determined by the ratio of the Target size to the separation between the cameras. For example, for a 30- μm Target, pointing drift will be limited to 60 μrad for a 0.5-m separation and 30 μrad for a 1-m separation.

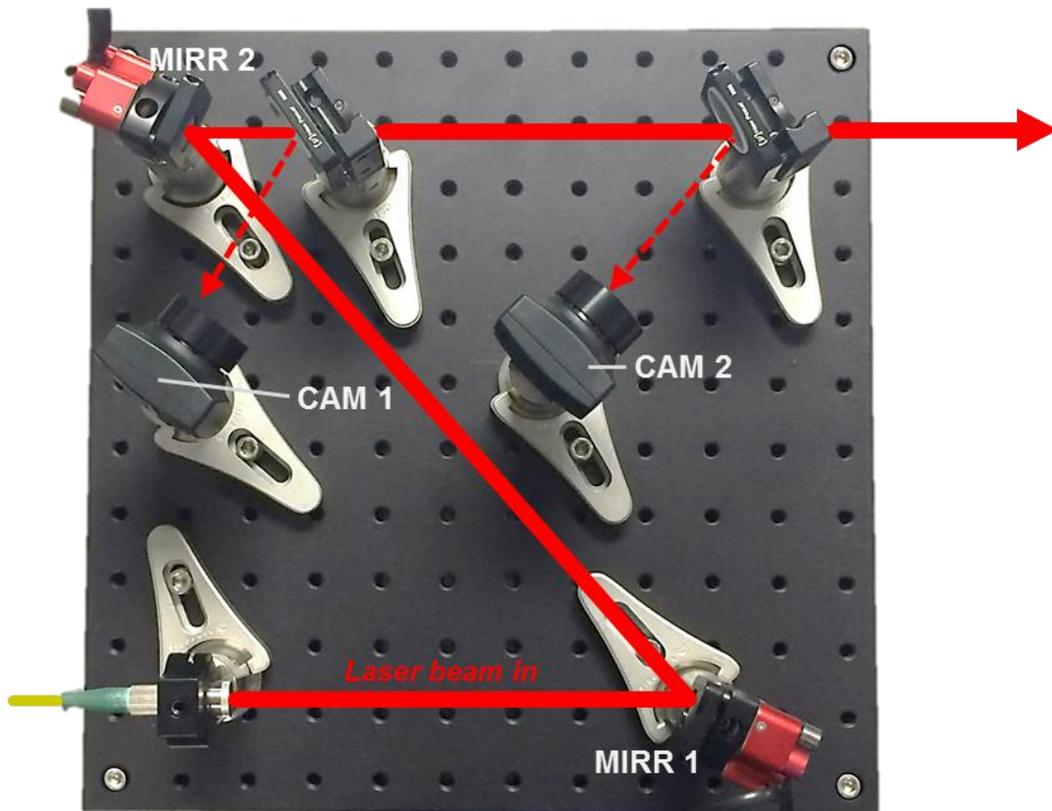


Figure 10. Example physical layout of mirrors and cameras for GuideStar II system.

To optimize performance, Camera 2 can be positioned so as to image a plane equivalent to the users working plane. This can be accomplished by setting the distance between the second pickoff and the working plane comparable to the distance between the second pickoff and Camera 2's object plane, which is about 4 cm in front of the lens. By doing this the beam position data and image shown by the GuideStar II software are essentially those of the working plane.

4.3.3 Connecting Hardware to the Controller

Figure 11 shows how to connect the mirrors and cameras to the GuideStar II Controller. These connections should all be made prior to launching the GuideStar II application. Failure to make these connections prior to opening the application may lead to an error message. If this occurs, close the GuideStar II application, make the necessary connections, and re-open the application.

Ensure that the x-axis and y-axis motor of Mirror 1 is connected to M1X and M1Y, respectively. Similarly, the x-axis and y-axis motors of Mirror 2 should be connected to M2X and M2Y. This is a common source of error that can be avoided.

The first Camera along the beamline is Camera 1 and it should be cabled to the Camera 1 USB port on the controller. Similarly, Camera 2 is connected to the Cameras 2 USB port on the controller.

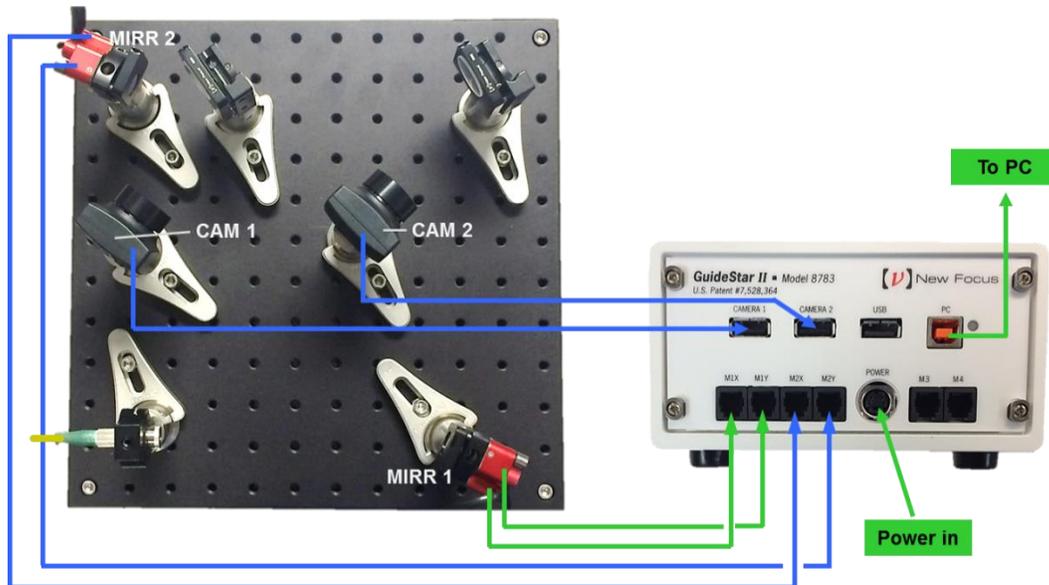


Figure 11. Layout of connections from Mirror Mounts and Cameras to GuideStar II controller

4.4 Software Operation

4.4.1 System Set-up

The first time the application is launched it will automatically open the System Set-up window and display the Camera Check tab:

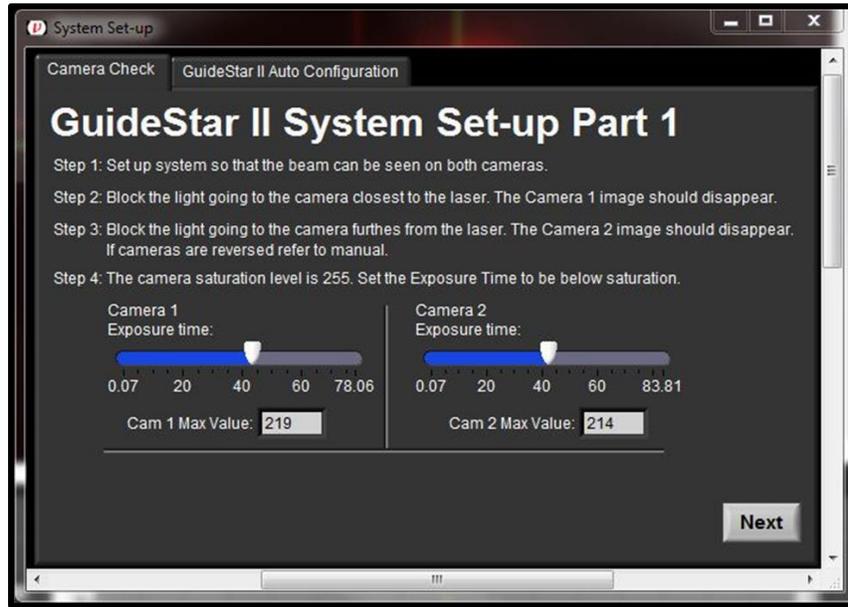


Figure 12. System Set-up window available through GuideStar II Tab.

This window cannot be closed until steps 1 - 4 are completed. If blocking the beams to the Camera 1 causes the Camera 2 image to disappear in the GuideStar II display (or vice-versa), then the camera IDs should be swapped. (For instructions on how to do this, see Section 6: Frequently Asked Questions.)

Now, click "Next" or click on the "GuideStar II Auto Configuration" tab:

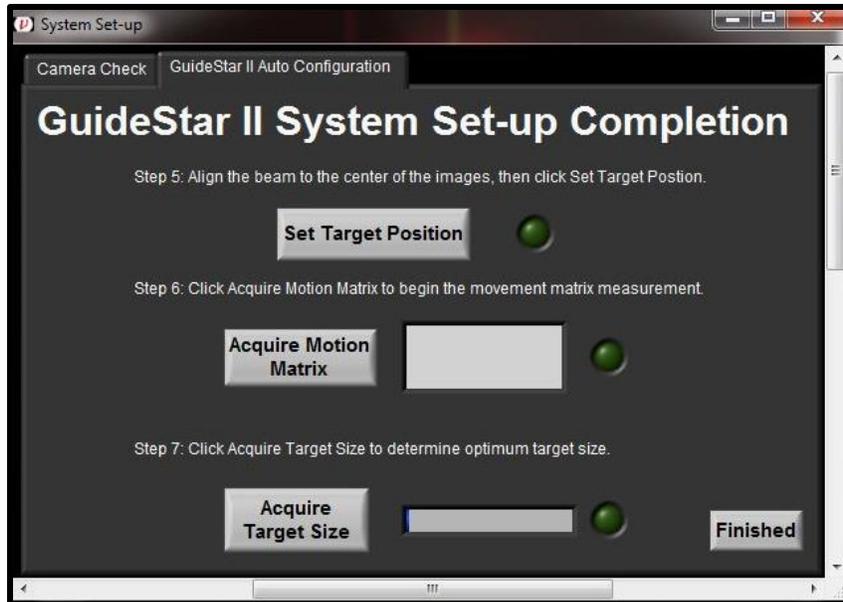


Figure 13. Example physical layout of mirrors and cameras for GuideStar II system.

In Step 5, you will set the target position. To do this, click the Set Target Position button. This will ensure that the system will return to the original alignment after the motion acquisition. Once the Target Position has been set, the green light next to the Set Target Position button will be lit. The target position can easily be re-set later if additional adjustment is desired. This is done by re-clicking the Set Target Position button.

In Step 6, you acquire the Motion Matrix. Click the “Acquire Motion Matrix” button. Over the next several minutes, the system will move each motor (X1, Y1, X2, Y2) by pre-defined amounts in the positive and negative directions and stop once it has gathered enough information or the beam has moved to the edge of the optical aperture. Once the Motion Matrix has been acquired, the green light next to the Acquire Motion Matrix button will be lit.

In Step 7, you acquire the target size. Click the “Acquire Target Size” button and the software will analyze the noise of the beam to determine a recommended target size for the motion settings. (The recommended target size can be changed later if desired.) Click the Finished button to close the System Set-up window and save the settings via the subsequent pop-up window.

4.4.2 Guide Star II Tab

The first tab of the GuideStar II program is labeled Guide Star II. On this tab is each camera’s image; a display of the target and centroid locations for each

camera; buttons for System Set-up, Camera Settings, and Motion Settings; indicator lights and a Lock On/Off button; and two controls for manually activating the motors:

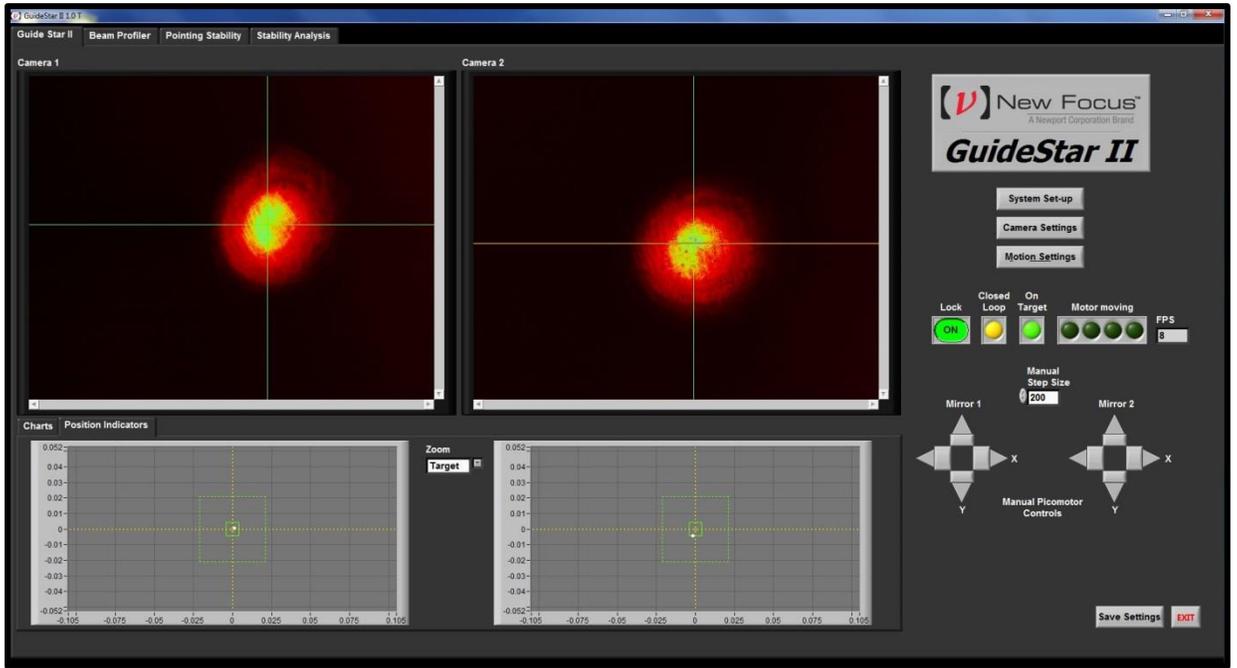


Figure 14. Screenshot of information and buttons available under GuideStar II Tab.



This button will turn off Lock and open the same System Set-up described Section 4.4.1. System set-up can be repeated at any time. To close the window, click on the Finished button on the GuideStar II Auto Configuration tab. A pop-up window will open in which you can save changes to the System Set-up.



This button will turn off Lock and open the Camera Settings window:

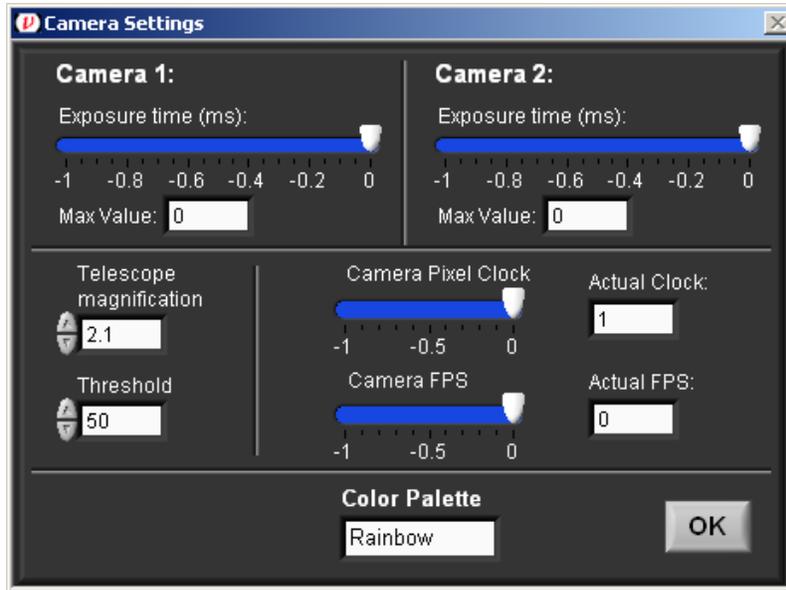
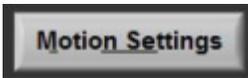


Figure 15. Camera Settings Window available through the GuideStar II Tab.

- **Exposure Times** should be set so that Max Value for each camera is below 255. The sensors saturate at Max Value = 255.
- **Pixel Clock:** At high Pixel Clock values (>20-25), a Pixel Clock Error may occur. The default value can be used in most cases.
- **FPS** (frames per second) A lower FPS will slow loop response but will permit longer Exposure Times. The default value can be used in most cases.
- **Telescope magnification** The default value should be used in most cases. This number is used to convert positions on the camera sensors to positions of the incident beam. Values of beam position and width reported on all tabs scale with this number. The default is the nominal value at the center of the image. Distortion is present towards the image edges.
- **Threshold** Pixel values below the Threshold will be ignored in centroid calculations. This is used to reduce effects of ambient or stray light.

To close the Camera Settings window, click on the OK button.



This button will turn off Lock and open the Motion Settings window:



Figure 16. Motion Settings Window available through the GuideStar II Tab.

- **Set Target Position** This button will reset the target centers to the current beam locations. This can be executed without the need to re-acquire the Motion Matrix.
- **Target Width** is the size of the Outer Target.
- **Inner Target Fraction** Target Width multiplied by the Inner Target Fraction gives the Inner Target size.
- **Loop Gain** When position Lock is on, and the beam moves outside the outer target, the motors are commanded to move the beam back to the Inner Target. The distance to the center of the Inner Target, scaled by the Loop Gain, is the size of the step taken. This parameter will influence the dynamic response of the control loop. It is recommended that one start with the default value and adjust it to achieve a well-behaved (no ringing, relatively fast) return of the beam to the Inner Target. A higher value will increase the speed of the loop response but may lead to ringing or erratic behavior. A lower value will give a well-behaved response but may make the response too slow. Typically, Loop Gain is set such that the beams are brought back to their Inner Targets within 2-5 seconds.
- **Inner Gain Fraction** This value will scale the loop gain once the beam is within the Outer Target.

- **Frames to Average Over** Determines the level of running averaging for centroid locations used in the control algorithm. As with Loop Gain, it is recommended that one start with the default value and adjust it to achieve a well-behaved (no ringing, relatively fast) return of the beam to the Inner Target. A higher value may slow loop response but may improve performance overall.
- **Acquire Motion Matrix** Click this button to initiate the routine to acquire the Motion Matrix. This only needs to be done during the initial system set up. This routine can take several minutes.

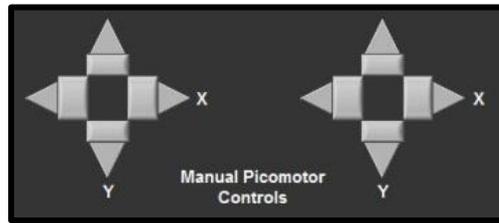


Figure 17. Example physical layout of mirrors and cameras for GuideStar II system.

- **Manual Picomotor Controls** The pair of four arrows with buttons provide manual control of the Picomotors. These can be used to manually position the beams during set up, and also to test the response of the control loop. By pressing a button while Lock is on, the dynamic performance of the loop can be evaluated. Set the Manual Step Size such that clicking an arrow will take the beams out of the Outer Target area. Ideally the beams will return to their targets in a relatively fast and well-behaved manner. This is a useful test when adjusting the Motion Settings (see below) to optimize loop performance.

To close the Motion Settings window, click on the OK button.

4.4.3 Beam Profiler Tab

Under the Beam Profiler tab basic beam profiling information is displayed. Also available is the Camera Settings button and a Pause button. The Full Size button under each image will enlarge the image. This can be reversed by hitting Esc on the keyboard. The Save Image button allows one to save a .JPG image to disk.

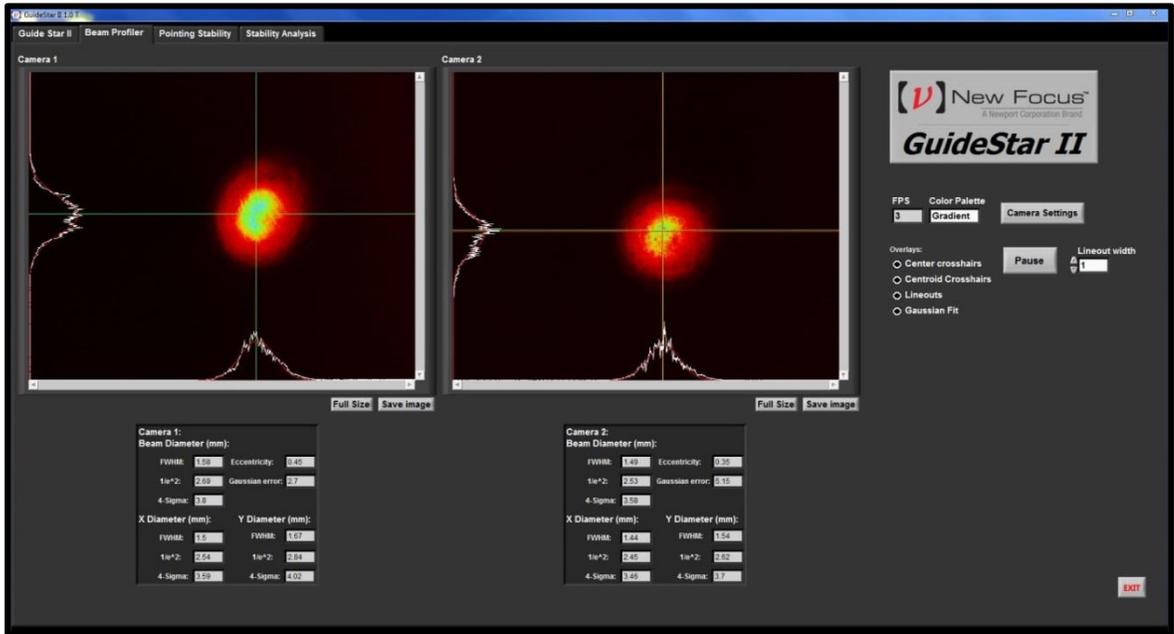


Figure 18. Example beam profile information available under Beam Profiler Tab.

4.4.4 Pointing Stability Tab

The Pointing Stability tab shows automatically generated graphs of the beam position data being gathered by the cameras. You can customize how much data is taken and save it to a .txt file.

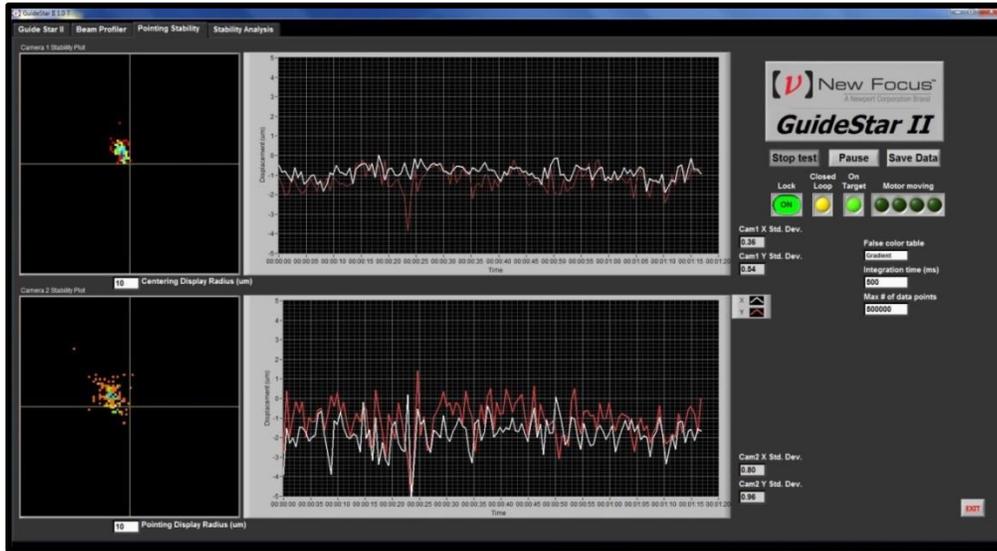


Figure 19. Example automatically generated graphs of beam position data found in Pointing Stability Tab

4.4.5 Stability Analysis

The Stability Analysis tab contains the individual data plots for X1, Y1, X2, Y2. This is the raw data as well as user-defined averaged data, and it is controlled by the Start test and Pause buttons on the Pointing Stability Tab. This data can be saved to a .txt file using the Save Data button.

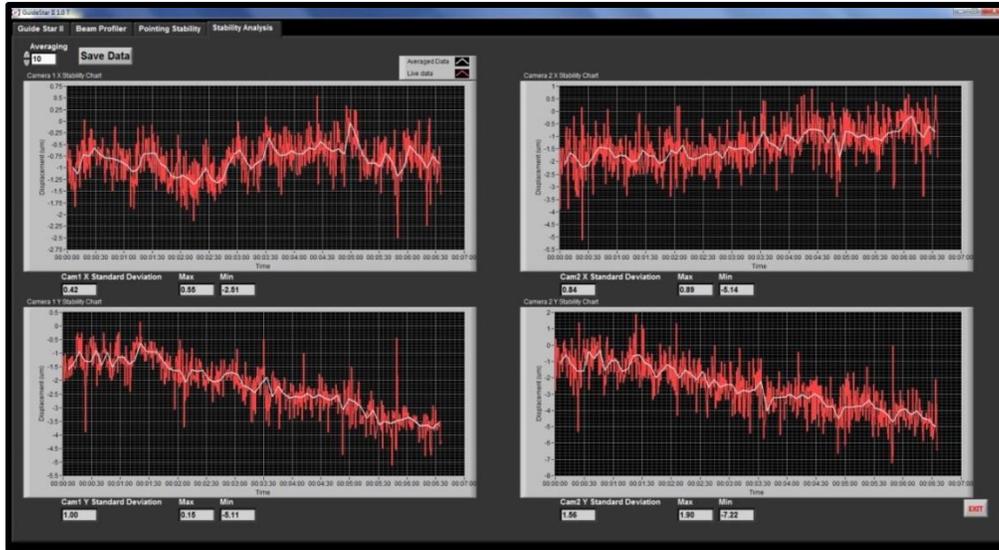


Figure 20. Example of individual plots of raw stability data collected for X1, Y1, X2, Y2 available in Stability Analysis tab

4.4.6 Changing Scales on Images and Charts

To change the scale of a chart: Autoscaling of the X and Y axes can be turned on and off by right-clicking on the graph or axis. For manual scaling, clicking on the maximum or minimum data label on an axis allows one to change its value.

To change the scale of a camera image: Move the mouse pointer over an image to enable the magnifying glass. Click to zoom in around the pointer location, or shift-click to zoom out. When zoomed in or out, an icon will appear in the upper right corner. Clicking this will reset the zoom so that the full sensor area is shown.

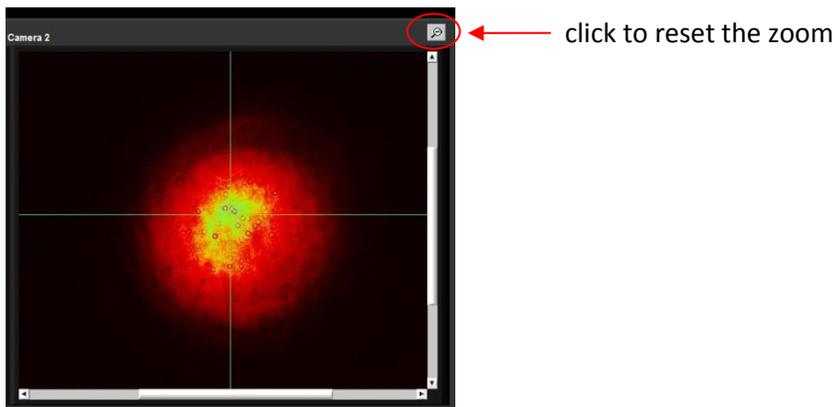


Figure 21. Example physical layout of mirrors and cameras for GuideStar II system.

4.4.7 Exiting the GuideStar II Application

To exit the GuideStar II application, click on the Exit button in the lower right corner. Then, the GuideStar II window can be closed by either clicking on the close box in the upper right corner of the window, or by going to File → Exit in the upper left corner.

5 Principles of Operation

5.1 GuideStar II Algorithm Theory

The control algorithm moves each Motor one at a time in accordance to the Lock Equation derived from the Inverse Movement Matrix, the difference between the current beam positions and the target beam positions and the gain coefficient.

Movement Matrix A

$$\begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{pmatrix} \cdot \begin{pmatrix} \Delta \text{MM1X} \\ \Delta \text{MM1Y} \\ \Delta \text{MM2X} \\ \Delta \text{MM2Y} \end{pmatrix}$$

$$\begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix} = \mathbf{A} \cdot \begin{pmatrix} \Delta \text{MM1X} \\ \Delta \text{MM1Y} \\ \Delta \text{MM2X} \\ \Delta \text{MM2Y} \end{pmatrix}$$

$$\begin{pmatrix} \Delta \text{MM1X} \\ \Delta \text{MM1Y} \\ \Delta \text{MM2X} \\ \Delta \text{MM2Y} \end{pmatrix} = \mathbf{A}^{-1} \cdot \begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix}$$

Above is the equation that would drive the beam all the way to the target in a single step. However, because of the nonlinearities in the system this leads to oscillation. Multiplying by a gain coefficient less than 1 leads to stable iterative convergence to the target in multiple steps.

$$\begin{pmatrix} \Delta \text{MM1X} \\ \Delta \text{MM1Y} \\ \Delta \text{MM2X} \\ \Delta \text{MM2Y} \end{pmatrix} = \text{gain} \cdot \mathbf{A}^{-1} \cdot \begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix}$$

5.2 Acquiring the Motion Matrix

During the Motion Matrix acquisition, each motor is moved, one-at-a-time and in both directions then returned back to where it started. The resulting beam movement is measured along the X and Y axes on each camera and this is used to construct the 4x4 Motion Matrix shown below. Each element A_{mn} in the matrix describes the motion resulting from the Motor movement from the m^{th} motor (i.e., four motors: Picomotor for horizontal motion on first Mirror Mount or MM_{1,x}, MM_{1,y}, MM_{2,x}, MM_{2,y}) along the nth camera axis (i.e., four axes: the x axis on Camera 1 or Cam_{1,x}, Cam_{1,y}, Cam_{2,x}, Cam_{2,y}).

Movement Matrix A

$$\begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{pmatrix} \cdot \begin{pmatrix} \Delta \text{MM1X} \\ \Delta \text{MM1Y} \\ \Delta \text{MM2X} \\ \Delta \text{MM2Y} \end{pmatrix}$$

For example, the motion along the x-axis of Camera 1 due to the x-axis Picomotor on Mirror Mount 1 is given by $\Delta \text{Cam}_{1,x}$ which is obtained according to

$$\begin{pmatrix} \Delta \text{CAM1X} \\ \Delta \text{CAM1Y} \\ \Delta \text{CAM2X} \\ \Delta \text{CAM2Y} \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & A_{14} \\ A_{21} & A_{22} & A_{23} & A_{24} \\ A_{31} & A_{32} & A_{33} & A_{34} \\ A_{41} & A_{42} & A_{43} & A_{44} \end{pmatrix} \cdot \begin{pmatrix} \Delta \text{MM1X} \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

However, this actuation will also move the beam along the y-axis of Mirror Mount 1, the x-axis of Mirror Mount 2, and the y-axis of Mirror Mount 2.

$$\Delta \text{ CAM1X} = A_{11} \cdot \Delta \text{ MM1X}$$

$$A_{11} = \frac{\Delta \text{ CAM1X}}{\Delta \text{ MM1X}}$$

$$A_{21} = \frac{\Delta \text{ CAM1Y}}{\Delta \text{ MM1X}}$$

$$A_{31} = \frac{\Delta \text{ CAM2X}}{\Delta \text{ MM1X}}$$

$$A_{41} = \frac{\Delta \text{ CAM2Y}}{\Delta \text{ MM1X}}$$

6 Frequently Asked Questions

What is the best layout of the mirrors and cameras?

The best physical layout of the Picomotor Mirror Mounts (MM) and Cameras (CAM) is such that the beam first strikes and is reflected off MM1 then MM2 with a small fraction of the light intensity then picked off for CAM 1 and CAM 2. Please refer to Fig. 22. The best physical layout will also maximize the separation between the two Mirror Mounts and between the two Cameras to give the most control and highest possible resolution. For example, a 60cm minimum distance between the two Mirror Mounts and between the two Cameras will give a resolution of or better than $10 \mu\text{rad}$.

It may also be useful to have the last camera image the actual working plane of the set-up so the system stabilizes exactly on what really matters.

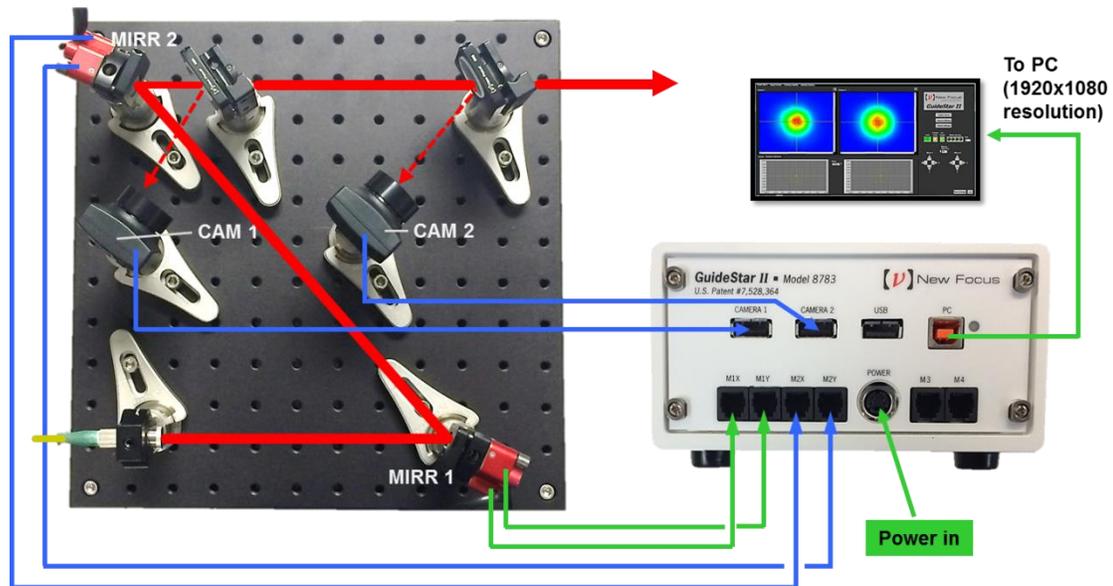


Figure 22. Example physical layout of mirrors and cameras for GuideStar II system.

How do I get a low power beam into the camera?

The power required to saturate the camera is generally very low so we provide ND-1,2, and 4 filters to attenuate any input and in the camera adjustments the exposure time can be varied by a factor of 1000 to further attenuate or optimize the measured intensity level. Low power beams can be measured, so it is not necessary to use the 4% reflections of uncoated surfaces. We recommend using the transmission through HR reflecting mirrors with polished back surfaces as the least intrusive method in a typical optical set-up.

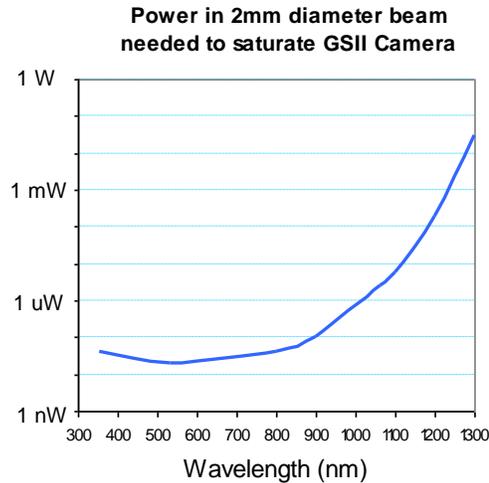


Figure 23. Example physical layout of mirrors and cameras for GuideStar II system.

What is the largest beam the system can measure?

The camera aperture is 12 mm so a larger beam will over fill the camera.

What is the limiting resolution of the camera?

The pixel size resolution of the CMOS sensor is $5.2\mu\text{m}$ but the beam position resolution is much smaller than this because the beam is measured over a large number of pixels. The camera position resolution noise had a standard deviation of $0.04\mu\text{m}$ and temperature drift coefficients of $3\mu\text{m}/^\circ\text{C}$ vertical and $0.5\mu\text{m}/^\circ\text{C}$ horizontal. With a 2.7:1 telescope all these numbers get multiplied by 2.7.

What is the temperature sensitivity of the cameras?

Measurements of beam position in a quiet environment have shown temperature drift coefficients of $3\mu\text{m}/^\circ\text{C}$ vertical and $0.5\mu\text{m}/^\circ\text{C}$ horizontal. With a 2.1:1 telescope these numbers get multiplied by 2.1.

What is the minimum angular change we can detect with the system?

The accuracy of the beam position specification of $25\mu\text{m}$ is conservative. The noise we see with a closed optical path measurement with no air turbulence over a minute is $< 0.1\mu\text{m}$. The angular change that this corresponds to depends on the

distance to the mirror from the camera but if we assume > 0.1 m distance then the angular noise is < 1 μ rad. In reality we see air turbulence and temperature drifts lead to beam noise of more than this but we have locked with targets sizes of 10 μ m and distances of 2 m so angular tolerances of < 5 μ rad.

What is the beam pointing which results from one step on a Picomotor?

A typical Picomotor step is < 30 nm and mirror mount lever arm is ~ 50 mm so the angular change with one step is less than 0.6 μ rad.

Do we have to set up the 2 cameras after the two mirror mounts?

It is common for set-ups to have CAM1 directly behind MM2. This is not a configuration we recommend because in this set up any movement of MM2 will have no effect on the beam going to CAM1 and so there are multiple solutions for the beam to hit the two cameras.

What should I do if I don't see the beam on one (or both) Camera(s)?

Make sure both cameras are connected to the Model 8783 Controller. If so, try lowering the Camera Pixel Clock setting to 10-20. If the problem persists, close the GuideStar II application and open the MicroEye Camera Manager program. Ensure that both cameras show up in the Camera List with the appropriate Camera ID.

How do I swap camera ID's:

Close the GuideStar II application and start the uEye Camera Manager. Both cameras should appear in the list. Select one, then click "Camera Information" and change its camera ID from 1 to 2 or from 2 to 1. Click "OK", and then do the same for the other camera. Close the uEye Camera Manager and restart the GuideStar II application. If the System Set-up window does not open after re-starting, click the System set-up button. Perform the camera check again.

None (or only one) of my Picomotors is moving either manually or automatically. How can I fix this?

First make sure that the each Picomotor is connected to its appropriate port on the Model 8783 GuideStar II Controller front panel. If so, it has been found that the best course of action is to un-install the GuideStar II application and all associated programs/files, then re-install. This will usually do the trick.

What is the advantage using CMOS camera instead of PSD?

The position measurement performances are similar but the camera gives information on beam size and shape as well. We use that information to make sure the stabilization routine is "smart" and does not have any unnecessary or dangerous beam steering.

7 Maintenance and Service

7.1 Warranty

New Focus, Newport Company, guarantees its lasers to be free of defects for one year from the date of shipment or for 3000 hours of operation, whichever comes first. This is in lieu of all other guarantees, expressed or implied, and does not cover incidental or consequential loss.

7.2 Technical Support

Information and advice about the operation of any New Focus product is available from our technical support engineers. For quickest response, ask for “Technical Support” when calling the numbers listed below and know the model and serial number for your product.

Hours: 8:00–5:00 PST, Monday through Friday (excluding holidays).

Toll Free: 1-866-NUFOCUS (1-866-683-6287), from the USA & Canada only

Phone: (408) 284-6808

Fax: (408) 980-4300

Email: techsupport@newfocus.com

We typically respond to faxes and email within one business day.

7.3 Obtaining Service

	<p><i>There are no user serviceable parts inside the Model 8783 Guidestar II controller. Work performed by persons not authorized by Newport Corporation will void the warranty.</i></p>
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The GuideStar II Controller contains no user serviceable parts. To obtain information regarding factory service, contact New Focus or your New Focus representative. Please have the following information available:

1. Instrument model number (on the rear panel).
2. Instrument serial number (on rear panel or bottom of enclosure).

3. Description of the problem.

If the instrument is to be returned to New Focus, you will be given a Return Material Authorization (RMA) Number, which you should reference in your shipping documents. Please fill out a copy of the service form, located on the following page, and have the information ready when contacting Newport Corporation. Return the completed service form with the instrument.

New Focus U.S.A.
Office: 408-919-1500
FAX: 408-980-6083

Name _____ Return Authorization # _____
(Please obtain RA# prior to return of item)

Company _____
(Please obtain RA # prior to return of item)

Address _____ Date _____

Country _____ Phone Number _____

P.O. Number _____ FAX Number _____

Item(s) Being Returned:

Model # _____ Serial # _____

Description _____

Reason for return of goods (please list any specific problems):

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