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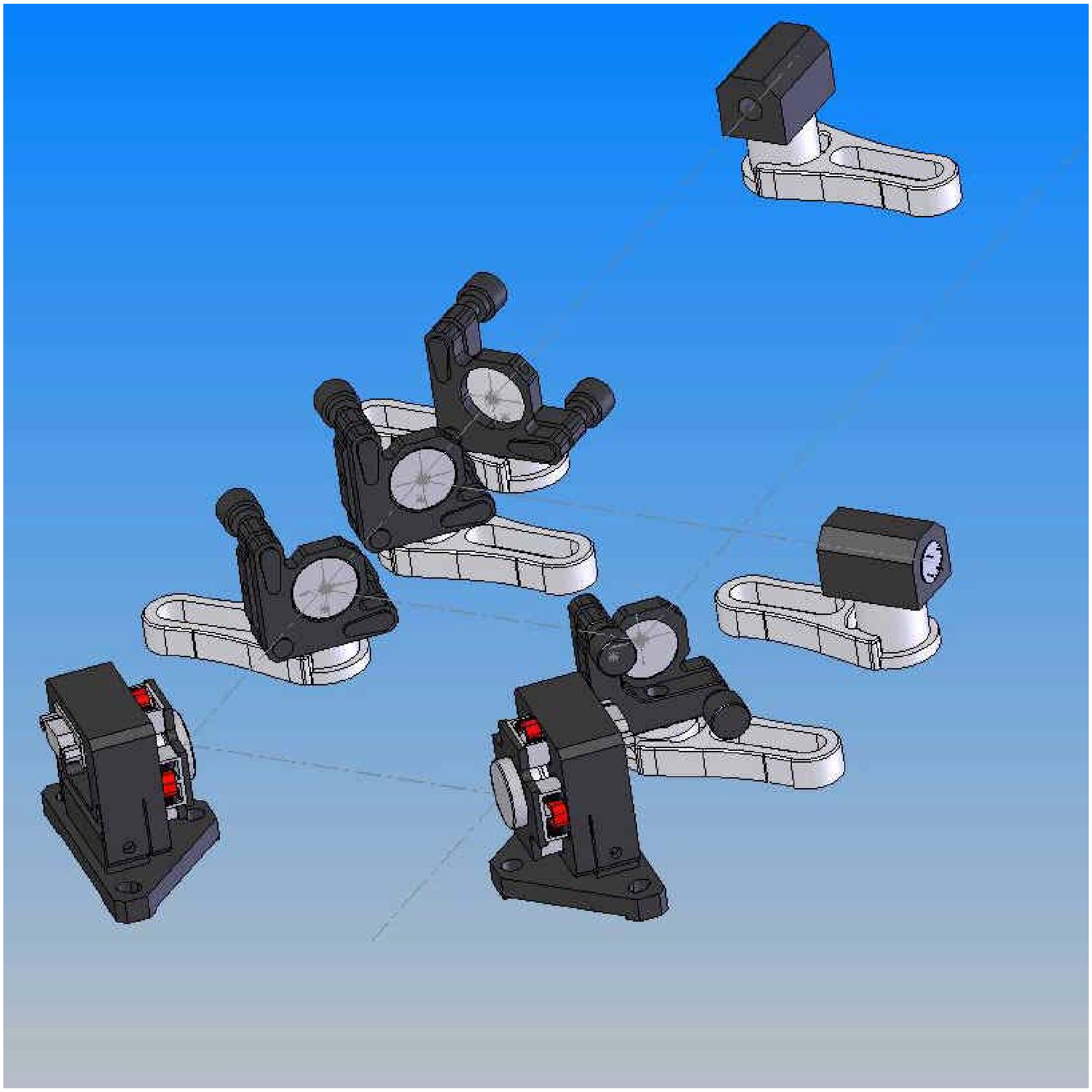
Beam Stabilizer



Optics In Motion

October 15, 2006
Revision D

Introduction:

Beam stabilizers are used to correct for dynamic laser beam pointing errors in optical systems. These pointing errors can be a combination of slow varying (thermal) and higher frequency error (mechanical vibration from fans, water pumps, etc.).

A beam stabilizer uses active mirrors to compensate for beam pointing errors. By sampling a small percentage of the beam, the actual beam motion can be tracked out using position sensing detectors.

Beam Stabilizer Configurations:

A beam stabilizer is made up a number of the following components:

1) Fast steering mirror - in our case a flexure suspended two axis voice coil mirror.

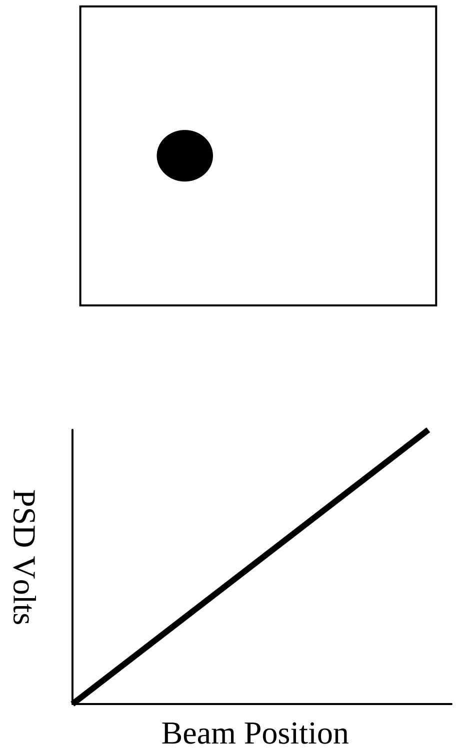
2) Optical Beam-splitter - a half silvered flat mirror that reflects some percentage of a laser beam while also transmitting a percentage.

3) Position Sensing Detector - either a lateral effect cell that outputs a voltage proportional to beam placement, or a quad cell that splits up the detector into 4 quadrants.

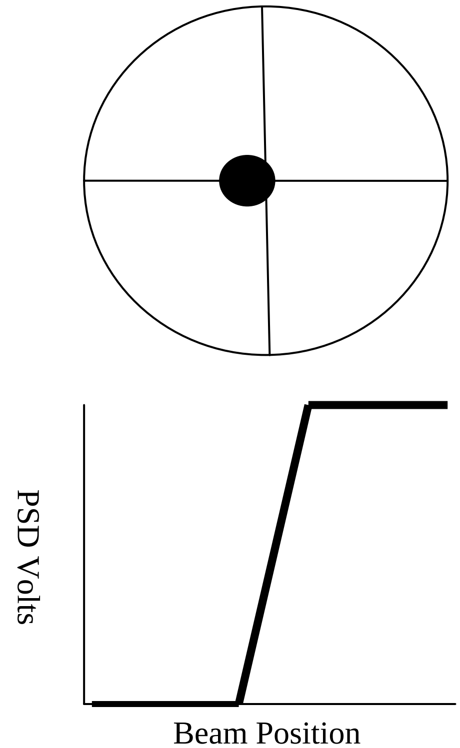
4) Imaging or focusing lenses – used either to transform angular error into displacement or to re-image an angular source.

Why would you use a lateral effect cell instead of a quad cell? A lateral effect cell measures the power centroid of a beam regardless of the beam size. A quad cell only measures position when the beam is split up into the quadrants of the cell. If the beam is fully on one quadrant the output will rail (either positive or negative)

If a lateral effect cell is used, the angular gain of the beam stabilizer mirror loop is dependent on the detector size and the distance of the mirror to the detector. If a quad cell is used, the angular gain is dependent on the detector size, the distance from the mirror to detector, and the beam size. See the graphs in figure x to see how beam size effects the mirror angular gain.



Lateral Effect Cell



Quad Cell

Note: Changes in beam size do not affect the later effect cell scale factor but they do affect the quad cell scale factor. (in volts/beam position)

Single FSM Stabilizers

It is possible to configure a beam stabilizer with a single FSM however there are drawbacks to this approach. In order to eliminate beam motion 4 degrees of freedom are necessary (to compensate for two displacements, and two tilts). A single FSM allows only 2 degrees of freedom, so proper placement of the error sources must be considered.

The simplest implementation of a beam stabilizer consists of a FSM, a beam-splitter, and a position sensing detector. The laser is reflected off the FSM and then passes through a beam-splitter. The majority of the energy is reflected and a small percentage is passed through the beam-splitter. The energy that passes through the beam-splitter is directed onto a quad cell.

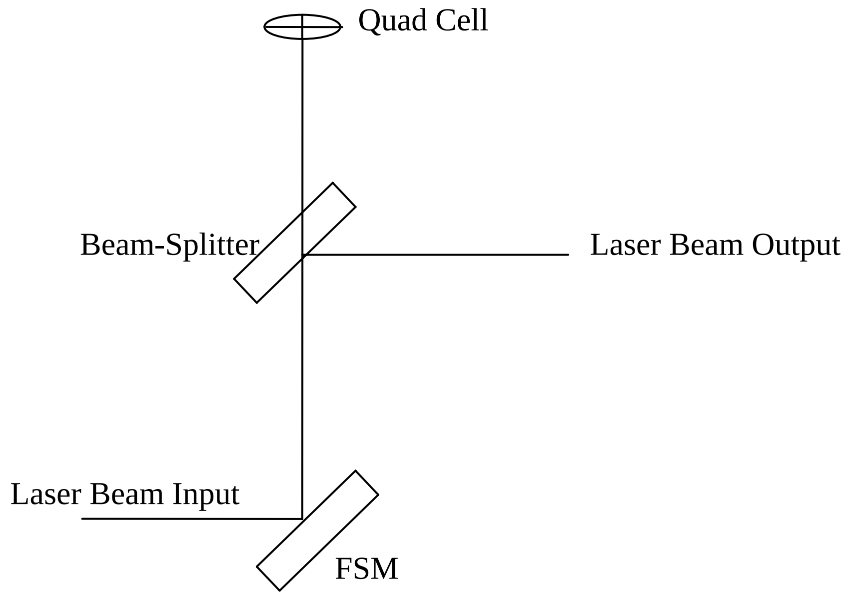


Figure 1. Simple Single FSM Stabilizer

As the laser beam drifts, the spot on the quad cell moves off center. Feedback from the quad cell causes the FSM to correct this motion and move the beam back to the center of the quad cell. The result of this correction is that the beam is held fixed at a point in space (the center of the quad cell). This may be an acceptable condition, but the beam angle is not controlled. In fact depending on the distance from the FSM of the angular error source compared to the distance from the quad to the FSM, the angular error may even be magnified. For example, if you wanted the angular error to be reduced by a factor of 100, then the distance from the FSM to the quad cell must be 100 times greater than the distance from the error source (usually the laser) to the FSM.

To eliminate this angular error, we can add a focusing lens in front of the quad cell. This lens is located one focal length away from the quad cell. This lens has the effect of eliminating beam translation errors from the quad cell output. Only beam angle change causes the spot to move on the quad cell. In addition, the spot on the quad cell is now focused, this has several affects on the beam stabilizer which will be covered in the setting gain section of this tutorial.

Now this simple beam stabilizer will correct for beam angle errors. However, beam translation errors will not be corrected. The magnitude of the translation error depends on the distance from the error source to the FSM. Another benefit of this design is that the distance from the FSM to the focusing lens can be a small as possible, larger distance does not improve the angular resolution of the stabilizer. The angular range and resolution is set by the choice of the quad cell and the focusing lens.

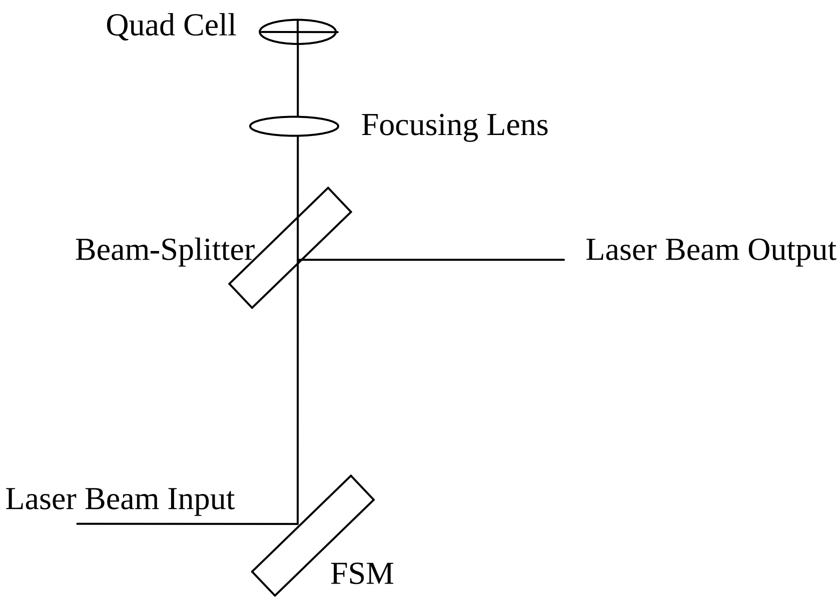


Figure 2. Single FSM Stabilizer with Focus Lens

In order to eliminate the translation effect, we need to insure that the angular error is relayed onto the surface of the FSM. If desired, the focusing optic can be eliminated and the stabilizer range and resolution will be a function of the distance from the FSM to the quad cell. This method works if there is no beam translation of the laser source, only angular errors.

Since the angular error occurs at the laser head, we need to add a set of relay optics that image the error source onto the face of the FSM.

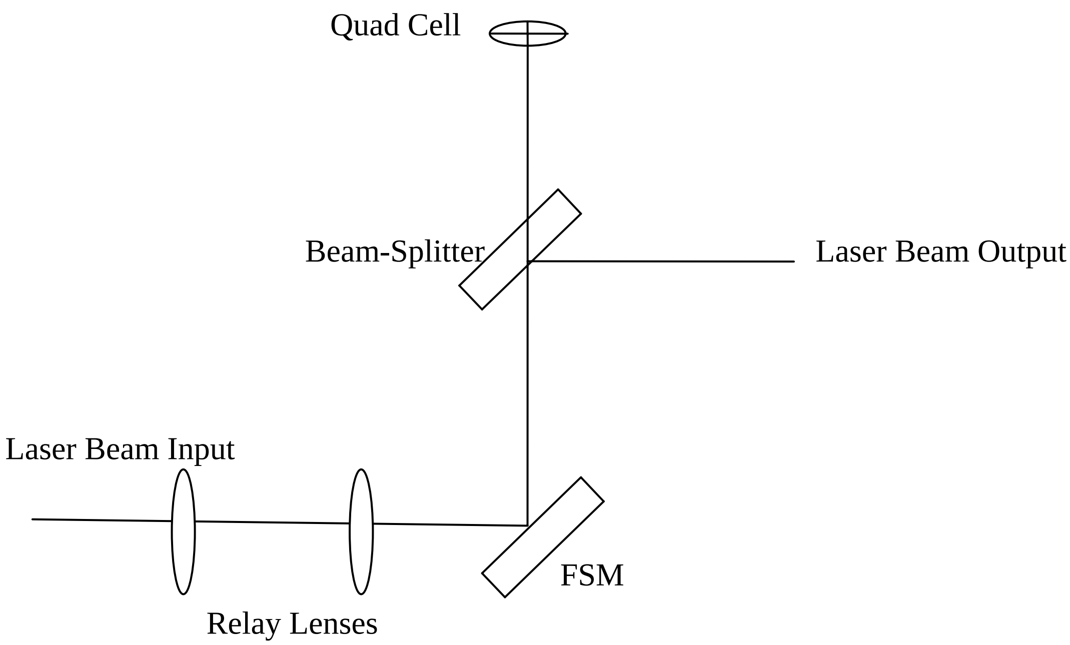


Figure 3. Single FSM Stabilizer with Relay Lenses

The distance from the first relay optic to the laser error source is one focal length of the relay lens. The relay lenses are spaced 2 focal lengths apart, and the FSM is one focal length from the second relay lens. Any angular errors at the laser source are relayed onto the face of the FSM at a single point. The laser beam then reflects off the FSM and through the beam-splitter and onto the quad cell. Since the spot on the face of the FSM is fixed, the quad cell reads only angular error which is fed back to the FSM to correct the error.

A simple test can be run to determine the effectiveness of this beam stabilizer configuration. By installing a relay lens set and placing a position sensing detector at the location of the FSM face, the resultant motion sensed by the PSD should be from any beam translation. If the magnitude of this translation is acceptable then this approach should work. Remember the resultant translation divided by the distance to the quad cell will be the resultant angular error in the system.

Dual FSM Stabilizer

A dual FSM stabilizer is more versatile than the single FSM stabilizers. This lends itself to simpler implementation. Systems can be built which act as a black box, with a laser beam input and a compensated laser beam output. Correction of both angle and displacement will be handed by the stabilizer without adding additional constraints to the optical system.

Two steering mirrors are needed to correct angular errors originating from a point at any distance from the front of the beam stabilizer unit. FSM1 corrects for errors in displacement of the beam from the reference line. FSM2 corrects for errors in angle of the beam from the reference line.
A schematic of a standard beam stabilization module layout is shown in figure 1. The heart of the system is the two FSMs and two position detectors. The position detectors are silicon quadrant detectors, which give feedback to the FSM's controller to keep the beam locked at the center. The beam input is at the bottom of the figure. Two 90 degree bends reproduce the beam's original direction with an offset. FSM1 corrects for angle due to the feedback it receives from Quad Cell1. FSM2 corrects for position due to the feedback it receives for Quad Cell 2. The beam position on Quad Cell 2 is an image of the spot on the front of FSM1. This is done by the lens which has a focal length of f/2 where f is the distance between FSM1 and the lens and also the distance between the lens and Quad Cell 2. This arrangement creates a relay lens which produces a spot on the detector that follows the spot on the front of FSM1. Since the two FSMs are operating independently they simultaneously correct for angle and position. The beam sampler takes a small percentage of the output beam (usually 1% to 5%).

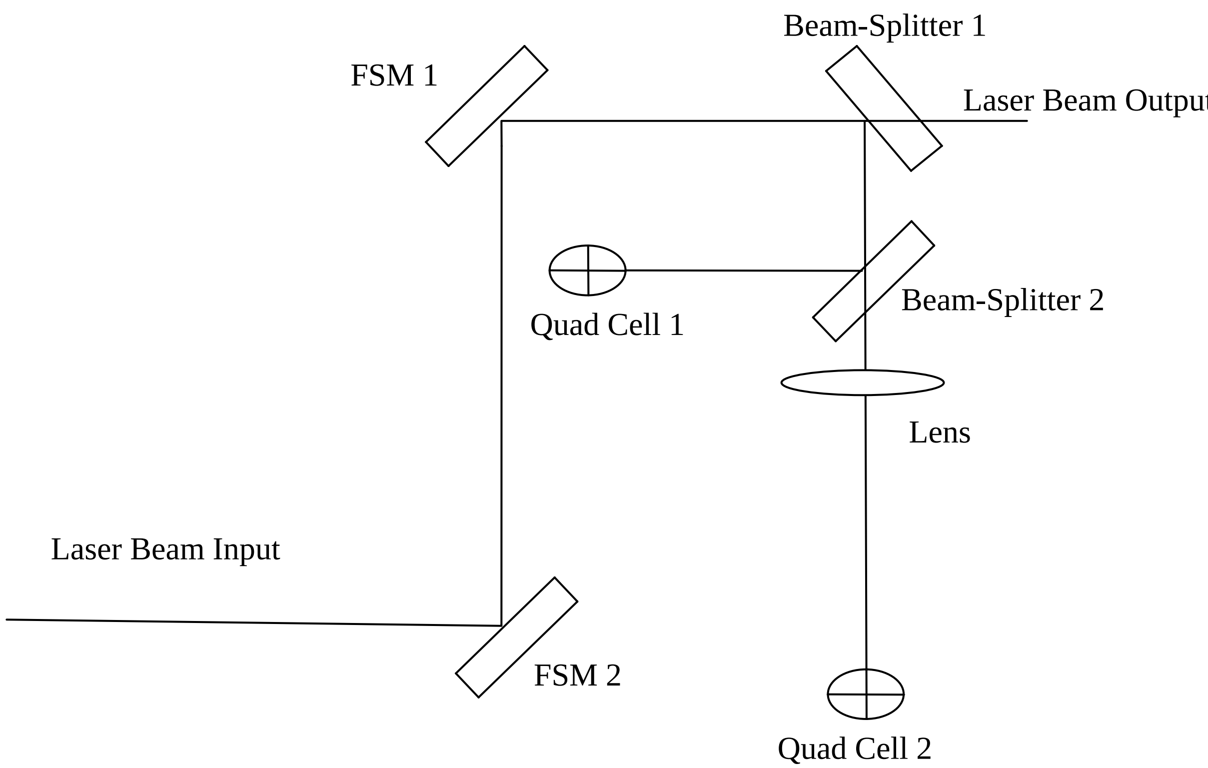


Figure 4. Dual FSM Beam Stabilizer

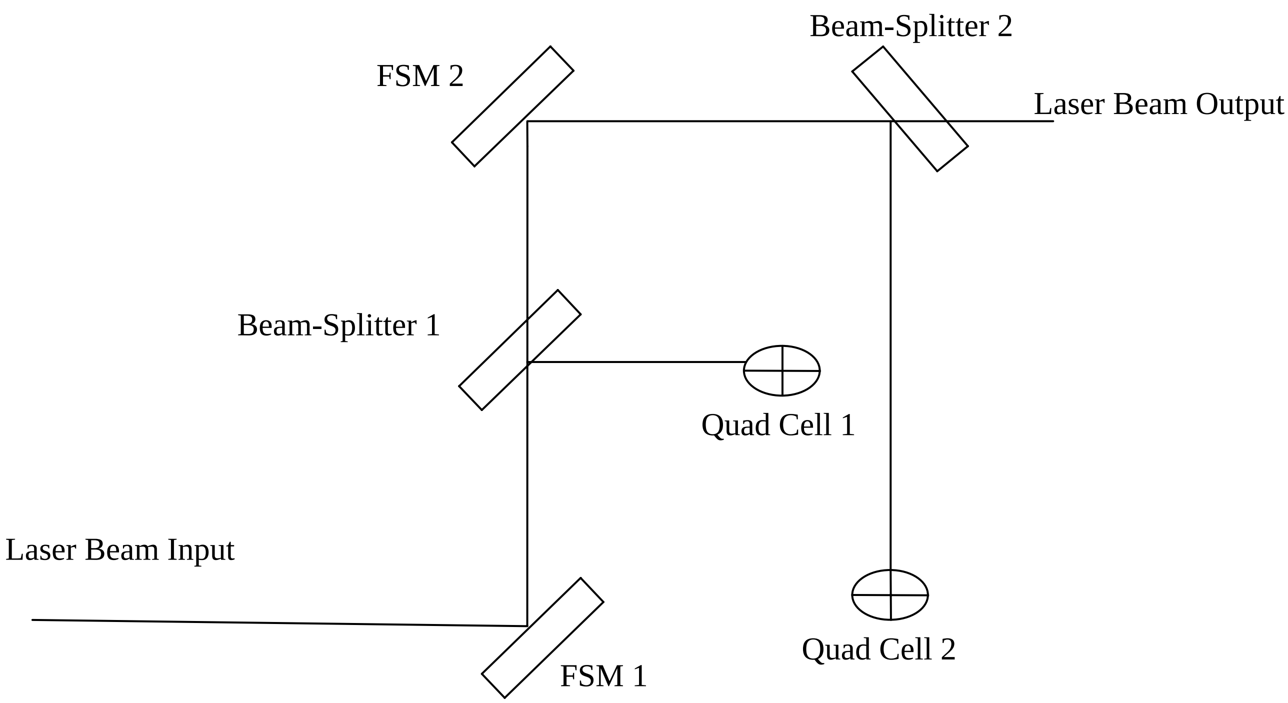


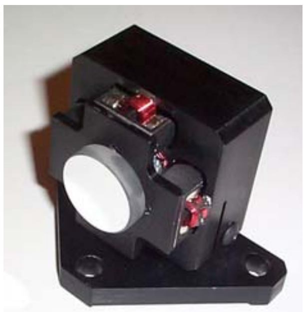
Figure 5: Alternate Dual FSM layout

The alternate dual FSM beam stabilizer shown in figure 5 uses two beam-splitters, and two quad cells. The distance from FSM 1 to FSM 2 is equal to the distance from FSM 1 to Quad Cell 1. This insures that the beam is stationary on the surface of FSM 2. An additional beam-splitter samples the beam and sends it to Quad Cell 2. FSM 2 removes the angular beam error. The advantage of this layout is that it does not need a lens, but the main beam has to pass through two beam-splitters.

Beam Stabilizer Users Document

Packing List

1) Beam Stabilizer Head
2) Beam Stabilizer Controller
3) Interconnect Cable
4) PSD mounted in a Thor labs holder
5) Power Supply
6) Power cable (wall plug to power supply)



1)

2)

4)

5)

Getting Started

Step 1) Become familiar with the operation of the beam stabilizer hardware.

Set up the simple layout shown in figure 5, using a single FSM, the PSD receiver, a laser source, and a beam-splitter. Place the detector ~20 inches from the FSM head.

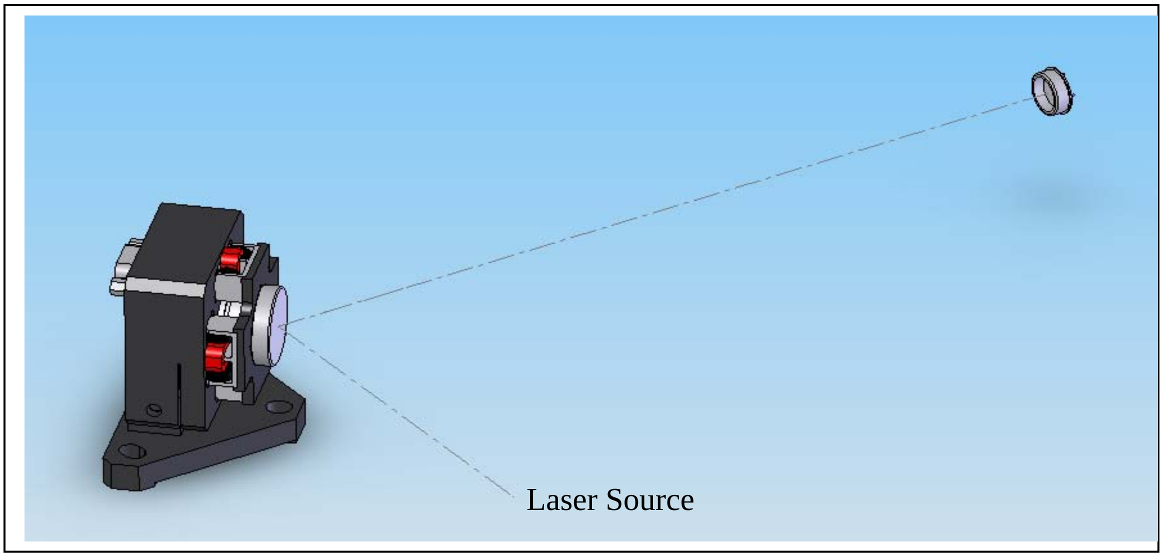


Figure 5. Initial Stabilizer Layout

Orient the PSD holder with the 8-32 thd mounting hold facing down (mounted to a post) as shown in Figure 6.

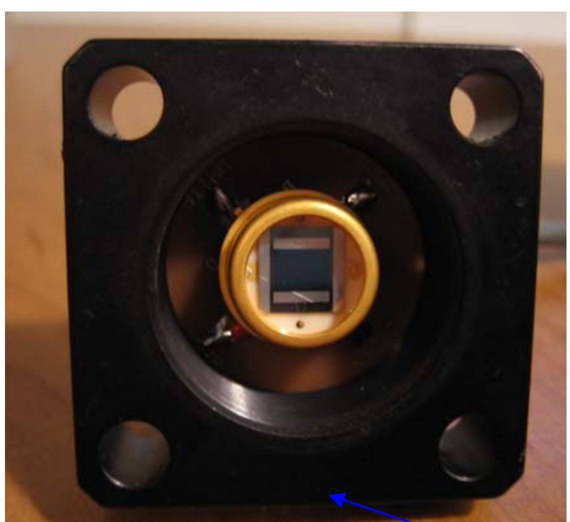


Figure 6. PSD Front View

Connect the 15 pin D-connector on the interconnect cable to the analog controller box. Power the controller using the supplied power supply. Do not connect the 9 pin D-connector to the FSM head at this time. Turn on the laser power and power the analog controller.

Make sure that the laser beam is centered on the detector. Remove the lens tube attached to the detector mount to verify the beam is on the detector. Replace the lens tube before continuing (lens tube and iris block room ambient light). Monitor the voltage using a voltmeter connected to Input\Output 25 pin D connector pin 21 and referenced to ground pin 6. Insure that the room lights are not effecting the reading by blocking the laser beam and verifying that the reading goes close to zero. If needed a 1 inch diameter narrow band optical filter can be installed into the lens tube to aid in reducing the ambient level. Adjust the laser power until the test point voltage is ~ 8 volts.

Turn off the analog controller power and connect the 9 pin D connector to the laser head. Turn on the controller panel and the mirror should be locked to the PSD. Verify proper operation by moving the PSD left and right and the mirror should follow.

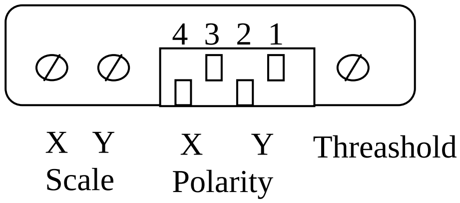
Adjusting Threashold:(CW increases threashold, CCW decreases threashold)
If the laser is blocked the controller “LOCK” led will light up showing that the loop is unlocked. The theashold potentiometer located on the front of the controller sets the voltage at which this switching occurs. Set the threashold level by monitoring the voltage on pin 8 of the I/O connector (again using pin 6 as the ground reference). When the loop is unlocked, the mirror is un-powered and returns to its rest condition. To adjust the threashold potentiometer, lower the laser power until the desired turn off level. Turn the potentiometer CCW until the loop shuts off.

Step 2) Setting the stabilizer up in your system

Now that you are familiar with the beam stabilizer hardware, you can start to arrange it into your configuration.

Adjusting Distance:(CW rotation increases scale, CCW rotation decreases scale)
As the distance from the FSM to the PSD is increased, the position gain also increases. When the gain gets too high the mirror will start to oscillate. To decrease the position gain, adjust the scale potentiometers on the front of the Beam Stabilizer Controller (CCW rotation). The X and Y scale should both be adjusted until the mirror stops oscillating.

Changing Polarity:
When you add a mirror to the system, the polarity in the x axis changes. To compensate for this change you need to flip the dip switch located on the front of the Beam Stabilizer Controller. Switches 1 and 2 control the y axis polarity (right two switches), and switches 3 and 4 control the x axis polarity (left two switches). Only one switch of the pair can be actuated at a time. (see switch position table bellow)



Polarity Switch Table (U- switch up, D – switch down)

4	3	2	1	
U	U	U	U	Both axes off (mirror disabled)
D	U	U	U	X axis enabled polarity 1, Y axis disabled
U	D	U	U	X axis enabled polarity 2, Y axis disabled
U	U	D	U	X axis disabled, Y axis enabled polarity 1
U	U	U	D	X axis disabled, Y axis enabled polarity 2
D	U	D	U	X axis enabled polarity 1, Y axis enabled polarity 1 (as shown in figure)
U	D	U	D	X axis enabled polarity 2, Y axis enabled polarity 2 (default setting)

Changing Loop Gain:(CW rotation decreases gain, CCW rotation increases gain)
The potentiometers located on the front of the analog controller set the PID loop gain. These should be adjusted to optimize the performance of the control loop. The loop gain should only be adjusted after the final configuration is assembled. Input a square wave with a 2 volt p-p amplitude centered about zero (+1 volts to -1 volts) into the x command connector located on the front of the analog controller. (a 25 pin D connector cable needs to be made up for this test). Monitor the x position on a scope (also from the same D connector). Adjust the x loop gain potentiometer until the square wave output is slightly over damped (no overshoot). This should be repeated for the y axis. This will optimize the loop performance of the FSM. (See Input\Output pin out table)

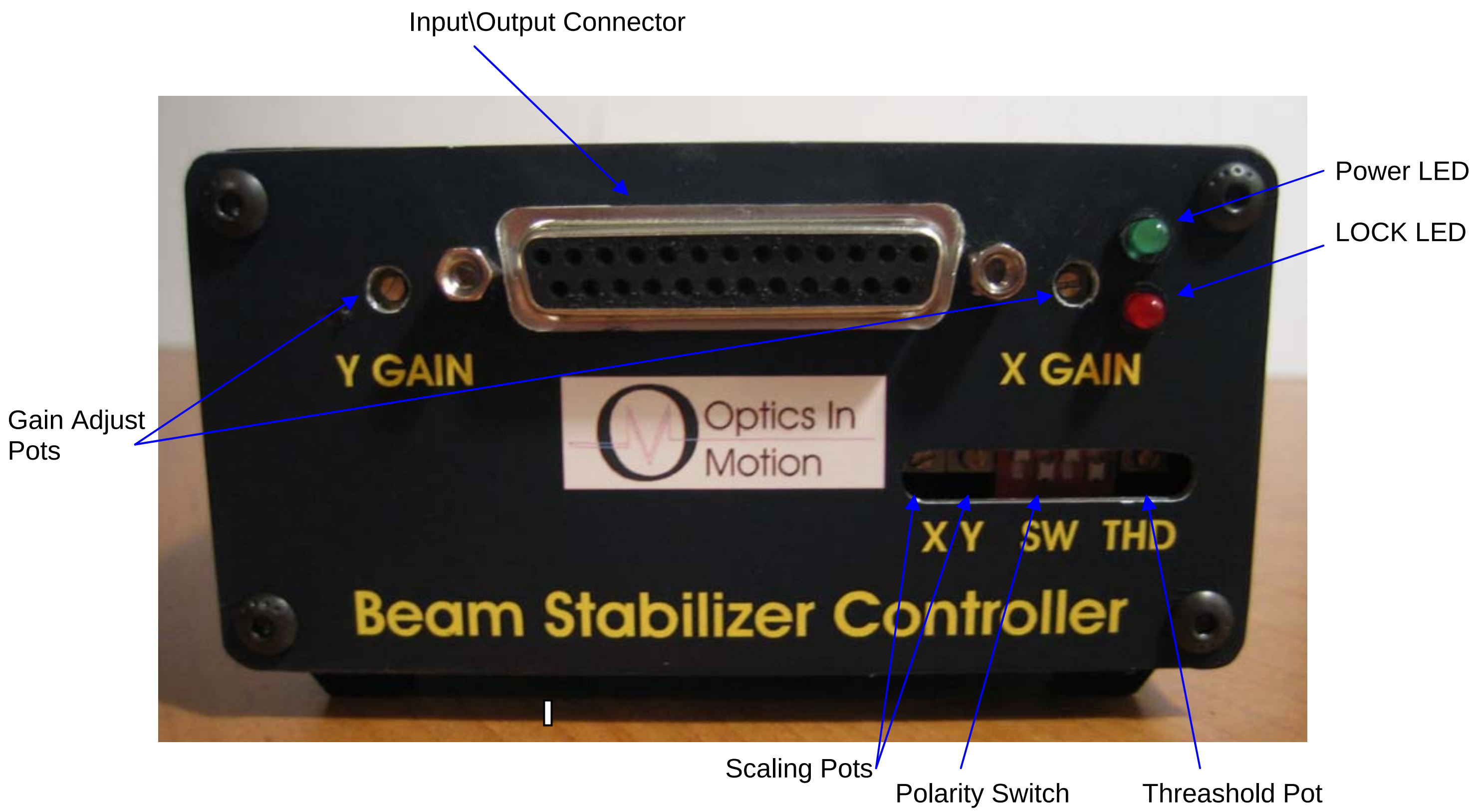


Figure 7 Beam Stabilizer Controller Front Panel

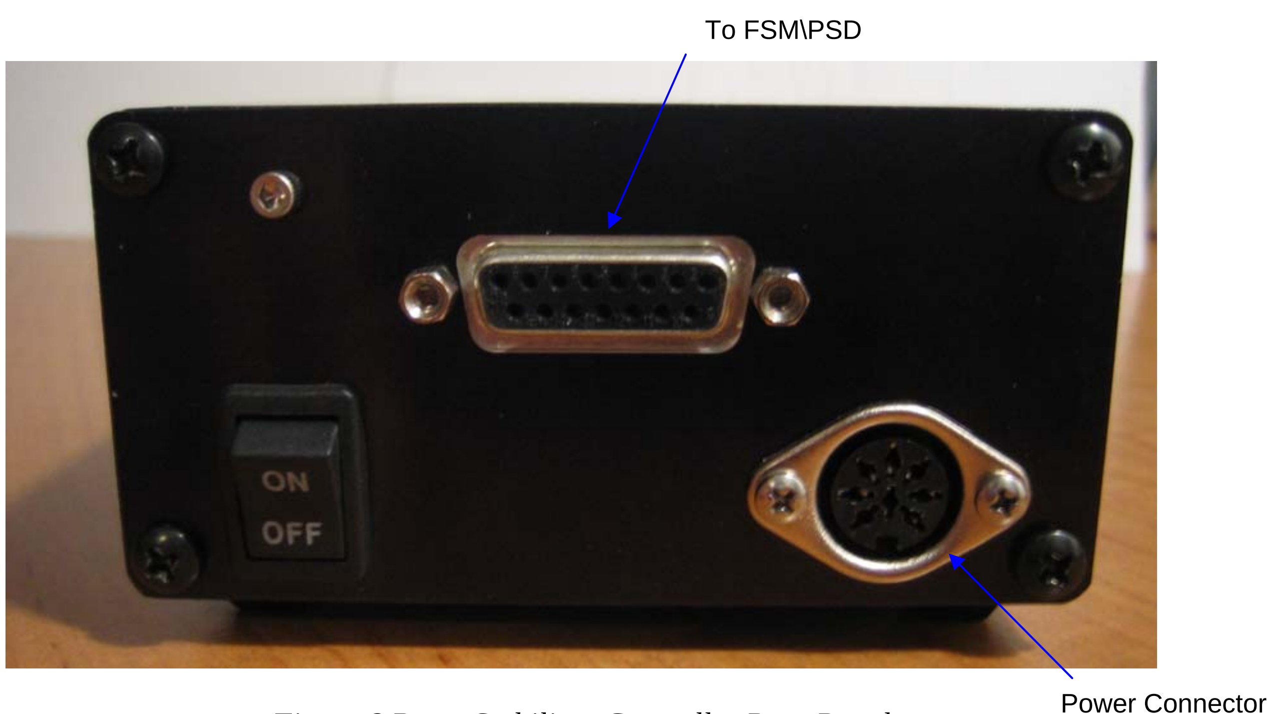


Figure 8 Beam Stabilizer Controller Rear Panel

Beam Stabilizer Command Connector Wiring Table

25-Socket Sub-miniature D Connector

Pin Number	Signal Name	I/O Type	Description
1	X ERROR	Output	X summing junction error voltage output, difference between commanded and actual position. (referenced to ground)
2	INT/EXT SWITCH		No internal position sensor on beam stabilizer mirror
3	X- COMMAND	Input	X mirror position command. Low side of differential command input. Range +/-10 Volts.
4	X+ COMMAND	Input	X mirror position command. High side of differential command input. Range +/-10 Volts.
5	X- EXTERNAL	Input	X external mirror position. Low side of differential position input (from external quad or similar position sensor)
6	GND		Ground Reference
7	-15 VOLTS	Output	-15 VDC for external loads of less than 100ma.
8	THREASHOLD	Output	Voltage output of the sum signal threashold level, used to set the mirror lock power level
9	N/C		
10	Y+ EXTERNAL	Input	Y external mirror position. High side of differential position input (from external quad or similar position sensor)
11	Y- EXTERNAL	Input	Y external mirror position. Low side of differential position input (from external quad or similar position sensor)
12	Y- COMMAND	Input	Y mirror position command. Low side of differential command input. Range +/-10 Volts.
13	Y+ COMMAND	Input	Y mirror position command. High side of differential command input. Range +/-10 Volts.
14	X POSITION	Output	X mirror angular position readout from local position sensor. (referenced to ground)
15	+5 VOLTS	Output	5 VDC for external loads of less than 100ma.
16	X POSITION RTN	Output	Ground
17	X+ EXTERNAL	Input	X external mirror position Low side of differential position input (from external quad or similar position sensor)
18	N/C		
19	+15 VOLTS	Output	+15 VDC for external loads of less than 100ma.
20	GND		Ground
21	SUM OUT	Output	Signal level on external PSD. Voltage output from 0-15VDC.
22	Y POSITION RTN	Output	Ground
23	Y POSITION	Output	Y mirror angular position readout from local position sensor. (referenced to ground)
24	Y ERROR	Output	Y summing junction error voltage output, difference between commanded and actual position. (referenced to ground)
25	LOCK OUT	Output	Normally low TTL output, High output represents a loss of signal on external PSD. Controller shuts down mirror operation until signal is sensed on PSD. Level set by threashold potentiometer.

Beam Stabilizer Mirror Block Diagram