APPLICATION NOTE

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Active Beam Stabilization Between Optical Tables

Technology & Applications Center,
Newport Corporation

Spectra-Physics
A Division of Newport Corporation

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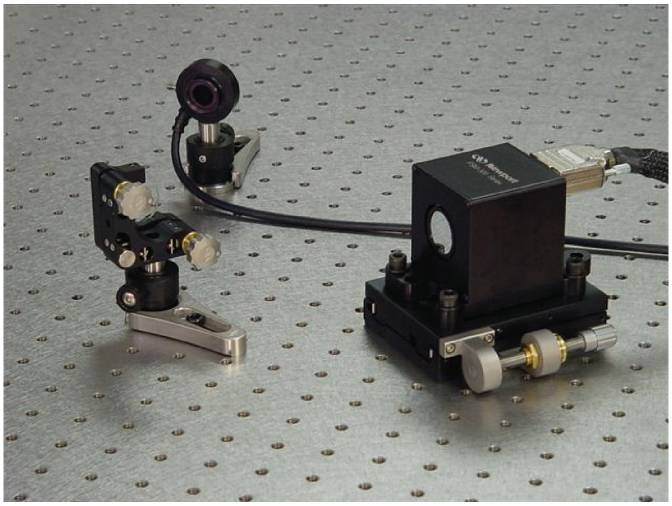


Introduction

Fast Steering Mirrors (FSM's) are commonly used in active beam stabilization systems where the laser and application fit on a single optical table. This active beam stabilization system corrects displacement and angular misalignment of the beam. Common sources that create these errors include vibration and turbulence, as well as thermal effects both internal to the laser and those affecting the lab environment.

In some cases, conditions such as space limitations, environmental factors or safety concerns require the laser to be isolated from the experiment. When this is the case, the laser and experiment are mounted on separate optical tables or housed in adjoining rooms. In other instances, budget limitations require that a single laser be shared between multiple experiments. In this case, the restricted allocation of resources limits the amount of time available for each experiment. As a result, the optical paths and/or experiments must be swapped out and realigned during transition from one experiment to the next. A more efficient time management strategy would be to allow all users unconstrained use of a portion of the beam, enabling them to maintain their setups and run their experiments concurrently. In each of these examples, a cost effective table-to-table active beam stabilization system can be implemented. This system would maintain a controlled beam between the laser source and its intended destination.

Manual alignment of folding mirrors between tables is simply not feasible. To maintain alignment, constant, simultaneous, manual adjustments of mirrors on both optical tables would be required to account for long-term drift, while transient errors could not be accounted for. Even though motorized actuators on the folding mirrors could be used in an automated mode to correct for long-term drift, the frequency response capabilities needed to correct for transient errors would be insufficient to maintain optimized alignment. Replacing the folding mirrors adjusted by manual or motorized means with Newport's FSM's allows for alignment corrections at a rate up to 1 kHz. This Application Note describes a simple kit comprised of FSM's and Optical Beam Positioning Instruments (OPI) allowing active beam stabilization for CW and pulsed lasers with repetition rate >5 kHz.

Layout and theory of operation

The layout presented in Fig. 1 demonstrates a simple means of active beam stabilization between two optical tables. A laser beam from one optical table is directed onto the center of the first Fast Steering Mirror FSM 1. As the beam crosses to the second table, it passes through a beam sampler BS 1, where a small portion of the beam is directed onto Position Sensing Detector PSD 1 of the OBPI, and gets centered on the second Fast Steering Mirror FSM 2. After reflecting from FSM 2 the beam passes through another beam sampler BS 2 where a small portion of the beam is directed onto PSD 2. When the system is active, external feedback from the Position Sensing Detectors of the OBPI's control the FSM's. The feedback from PSD 1 is used to correct for pitch/yaw and lateral displacement via FSM 1 in order to maintain the beam on the center of FSM 2. The feedback from PSD 2 is used to correct for any remaining pitch/yaw via FSM 2. This correction maintains the beam alignment from FSM 2 to the experiment. To achieve the best results, the optical path lengths from beam sampler BS 1 to both FSM 2 and PSD 1 need to be equal.

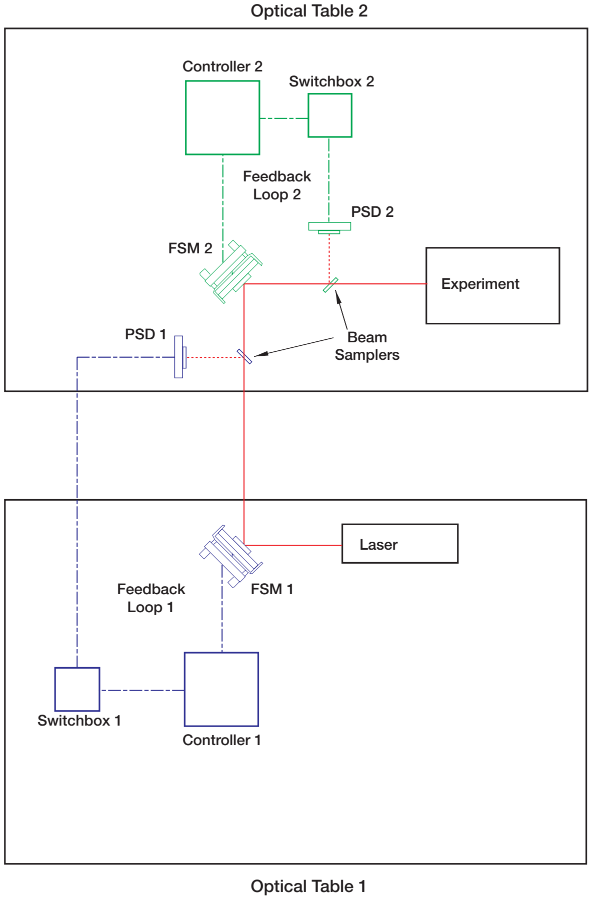


Fig 1. Active beam stabilization between two optical tables.

As previously mentioned, the beam should be maintained at the center of the mirrors to achieve the best performance. Since the surfaces of the mirrors of the FSM's are 12.19 mm in front of the gimbal point, angular corrections will introduce slight translations. These are minimized at the null position and will be compensated out through the servo feedback loop from the PSD's.

The FSM's are placed on Newport 433 stages at 45° to the beam path in order to facilitate centering of the beam on the Fast Steering Mirror. It may be easier for the user to stack two 433 stages along the beam path, which may limit the minimum beam height.

A similar option exists with the adjustment of the PSD's. Current methodology uses the reflection off the beam samplers to adjust the beam centroid onto the PSD's. The subsequent correction of the feedback system to drive the beam to the zero point of the sensors affects the beam path, and the beam may move from the center of FSM 1 or the input angle into the destination target may be slightly off.

Different laser wavelengths and/or power levels may require different beam samplers, mirrors and filters to avoid saturation of the PSD's.

Switchbox

Frequency response of the system is also critical. If there is too little gain in the control loop, corrections will lag. Likewise, if there is too much gain, the system will oscillate. In each of these cases, there will be an unacceptable amount of movement of the corrected beam. As the path length varies, the gain of the feedback loop from the PSD's to the FSM controllers will need to be adjusted. As the distance increases, the gain will need to be reduced as small movements over greater distances result in larger excursions from the zero point on the PSD's. There has to be an easy way to make this adjustment to the system gain.

Another concern is the rotation and polarity of the PSD sensor relative to the FSM feedback. The PSD can be mounted in four orientations, so a relative beam movement on the sensor can result in a feedback signal that can be applied to tilt the mirror about the X+, X-, Y+, or Y- FSM axis. Folding mirrors in the beam path prior to the sensors also can rotate the coordinate system or flip the polarity of the feedback. It is therefore necessary to make adjustments for changes in polarity to both X and Y axes of rotation for both of the PSD's.

In its default condition, the FSM is controlled by an internal feedback loop. In order to switch to external control and use the PSD's as the feedback source, a TTL High signal needs to be sent to the Interface I/O. It is the external feedback that controls the stabilized beam alignment on the target destination. This TTL signal is effectively the On/Off switch for the Active Beam Stabilization System. If any of these conditions are not controlled or accounted for, the system will rail.

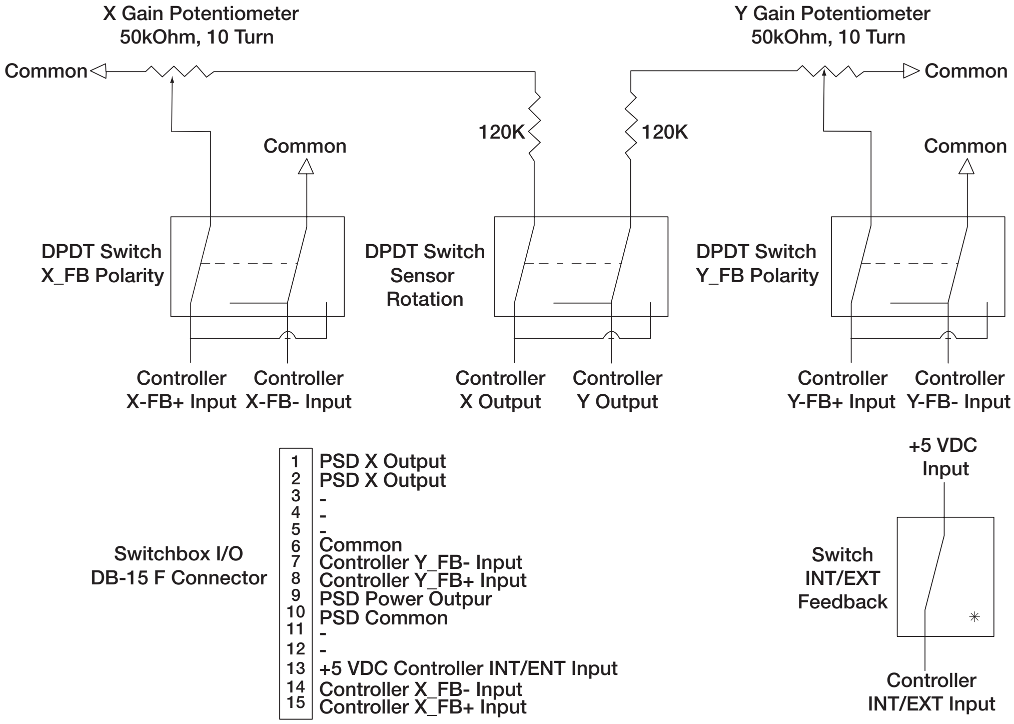
Internal/external feedback switching, gain adjustment, X and Y axis and feedback polarity selection, along with interfacing between PSD's and FSM's can be built into a single box to control each FSM. A schematic is shown in the appendix.

In Newport's Technology & Applications Center, such a system is used to transfer a laser beam between two vibration isolated SMART optical tables. In this particular application the distance between the FSM's is 3250 mm (> ten feet) and the distance from FSM 2 to the experiment is an additional 1850 mm (> six feet). PSD 2 is placed within an inch (25.4 mm) of the experimental setup in order to maximize performance. While actively disturbing Optical Table 1 at 1 Hz to produce an angular misalignment of +/- 0.5 mrad, a PSD at the location of the experiment will see an offset of less than 20 µm. Without Active Beam Stabilization System, the beam would be offset +/- 25.5 mm (> +/- 1 inch). For less extreme disturbances, the beam pointing stability is limited by the angular resolution of the FSM's, which in this case leads to 2.0µm displacement at the location of the experimental setup.

A schematic for the interconnect cable is shown in the appendix. The cable is pigtailed from the 15-pin sub-d connector at the switch box, to the Interface I/O port of the controller and the analog outputs of the PSD. A 25-pin sub-d connector is required to connect to the Interface I/O connector on the FSM-CD300B Controller/Driver. The other half of the pigtail cable is wired directly to the analog inputs of the PSD interface. The length of the feedback wire is dependant upon the distance between the PSD and the associated FSM. For the loop between FSM 2 and PSD 2, this is generally less than 3 feet. For the loop between FSM1 and PSD1, where FSM1 resides on one table and PSD1 resides on the other, the length of cable is determined relative to the distance between tables.

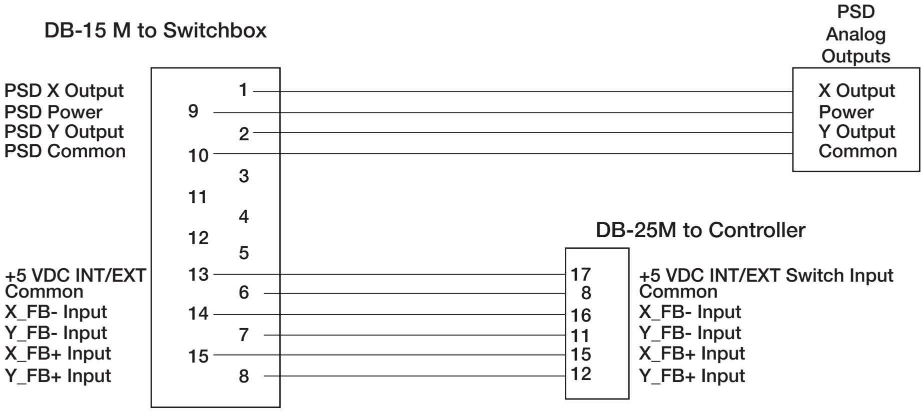
Appendix

Switchbox Schematic



Gain adjustments are made by changing the resistance across a 10-turn, 50 k ohm potentiometer. There are four toggle switches for the other controls. One switches between internal and external feedback. Another changes the feedback rotation from the PSD relative to the FSM. This allows the user freedom in setting up the PSD without being constrained to a particular orientation. As the PSD rotates and various folding mirrors are introduced to the system, the feedback polarity may need to be switched for each axis. Separate switches change the feedback polarity between X+/X- and Y+/Y-. A 15-pin sub-d connector cable is used to interface between the PSD and the FSM controller/driver through the switch box. Two C-cell batteries in series are used to generate the TTL signal. Although not 5V, it is sufficient for the FSM controller to differentiate between high/low states.

Interface Cable Schematic:



Newport Parts List:

(2X)	FSM-300-01	Fast Steering Mirror System with 1" mirror, ER.1 coating
(2X)	433	Precision stage
(2X)	SM-13	Precision micrometers for above
(2X)	OBP-A-9H	Optical Beam Position Sensor, Analog, 9 mm square sensor, High Res.
(2X)	LBP-NG9	NG9 Attenuator
(1X)	ULM-TILT	Laser Mount with High-Resolution AJS Adjusters
(1X)	370-RC	Rack and pinion rod clamp
(1X)	75	Damped rod with rack
(2X)	SN100-F2KN	Suprema mounts, 1", 2 knobs, Clear Aperture, Front Load,
(2X)	10B20NC.1	1", 1/10 λ, 400-700 nm, Beam Samplers

These beam samplers will work throughout the visible light range. Newport also offers broadband beam samplers covering 660-1000 nm and 1010-1550 nm ranges, as well as beam samplers for ultrafast lasers. Please contact tech@newport.com for Technical Support.

(4X)	PS-F	Pedestal Clamping Fork
(2X)	PS-2	2" Pedestal Post
(2X)	PS-1	1" Pedestal Post
(2X)	PS-0.5E	0.5" Pedestal Post Extension
(1X)	SK-08A	8-32 screw kit
(1X)	SK-25A	1/4-20 screw kit
(1X)	TA-8Q20-10	8-32 to 1/4-20 Thread Adapters
(1X)	TA-8M6-10	8-32 to M6 Thread Adapters

Thread adapters will be needed to attach PSD's to Pedestals. The pedestals accept 8-32 threads and the PSD's accept both 1/4-20 and M6 threads. The particular thread adapter needed will depend on the orientation of the PSD.

Customer Supplied Items

(1X) Laser

(2X) Switchboxes (customer built)

(2X) Switchbox interface cables (customer built), length of cable between controller and switchbox dependant upon spacing between optical tables.

Additional Information

Cascading setup

You can use multiple Active Beam Stabilization Systems to cascade the beam to multiple tables.

Riser setup

You can also incorporate risers to the setup as a means of passing the beam from table to table above the height of user traffic. This will require additional mirrors, mounts, brackets and risers. Contact Newport for further information.

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