PIEZO ACTUATORS PROVIDE FLEXIBILITY TO LASER DESIGNERS USING COMPACT OPTICAL MOUNTS AND MOTION STAGES

I. INTRODUCTION

Lasers require precise alignment in their design to simultaneously deliver optimal power and provide ultra-stability of the beam in position and quality. To meet this requirement, the laser designer must precisely control the optical path inside the laser. Guaranteeing a high level of precision and enabling nanometer level linear displacement and µrad rotation level, Newport™ piezo products are ideal components to ensure the performance and quality of the laser beam over the long term and permit flexibility in the design.

II. Problem

The design of lasers requires very high precision in assembling the components and sub-assemblies that constitute them. In particular, the optical path must be precisely aligned to avoid any power loss or risk of damage to the internal components, given the energy carried by the laser beam. The Picomotor™ and Agilis™ series actuators associated with Newport optical mounts can control the positioning/alignment of the laser beam and realize the necessary trajectory corrections to maintain an ideal optical path. This level of precision is particularly important in optical designs that extend to several meters inside the laser.

We identified three applications for piezo actuators and optical mounts in lasers:

- The first application is maintaining correct positioning of the laser beam between the various internal components and, if necessary, being able to adjust the alignment without any manual service operation.
- The second application is moving the laser's point of incidence on a non-linear crystal after surface damage/ wear and extending the useful life of the crystal. In this case, a new area of the crystal surface is utilized, extending its lifetime without replacing it or performing a time-consuming maintenance event. It has the additional benefit of being done without opening the laser, eliminating any contamination risk.
- The third application is precision linear motion (e.g. Agilis) to enable moving optics to compress or stretch the pulse width and act on the Group Delay Dispersion (GDD) in ultrafast lasers.

The Picomotor actuators and optical mounts associated with the dedicated controllers offered by MKS Newport are ideally suited to these applications because of their extremely fine resolution step, they allow stable and exact positioning (step < 30 nm, angular resolution <1.5 µrad, no backlash) for the optical component, which can be a mirror or lens while occupying a restricted volume.

III. State of the art

Numerous laser manufacturers use Newport products in their laser systems. Their optical path includes the Picomotor and Super Agilis Series associated with Newport optical mounts. These devices are considered industry standard for the different applications listed above. In the laser optical path, often more than a meter long, our products are guaranteeing that the beam travels correctly from one internal module to another. Use of these devices enables the lifetime extension of the module comprising the non-linear crystal, which has the shortest lifespan and thus reduces the Total Cost of Ownership, or TCO, of the complete laser. The system usually includes a feedback loop to identify when the system is aligned. It could be a photodiode measuring either position or power through the reflection of the

signal. The end-user initiates the laser beam recalibration operation. Indeed, this operation must not occur unexpectedly when a job is ongoing, as it can damage the sample. It must be done after a proper warm-up of the system (stable environment). The nanometer/µrad level steps and the extremely reliable position holding without power consumption of the Newport Piezo products make them ideal to guarantee both the stability of the process and to improve its robustness since the laser beam is perfectly controlled and operates permanently in the optimal conditions. No overheating is generated by the piezo and these devices are fully compatible with the level of cleanliness required in lasers: no particles and no organic material are emitted by the piezo devices. These products are also compatible with usage in vacuum conditions.

This monitoring and calibration system is not only useful to reduce maintenance but also improves the quality of the manufactured parts or processed operations since the laser always works in optimal conditions at the required levels of precision and quality. In addition, it is possible in an Industry 4.0 environment to link the quality of the manufactured parts or operations to the laser calibration parameters. This enables the operator to plan preventive maintenance campaigns when the quality of the result obtained begins to drift from the optimal values.

The Newport piezo actuator family differentiates itself by providing very small steps, superior repeatability, and compactness. In addition, the range of Newport controllers provides a very compact and economical solution for driving piezo actuators (Picomotor and Super Agilis, closed-loop control for fine tuning, absolute positioning).

IV. Solutions

Below are some reference use cases illustrating the applications described above where Newport piezo actuators are particularly well suited.

Principle of laser beam alignment Figure 1:

- Two adjustable mirrors are used to align the laser beam inside the laser and maintain a fixed optical path to avoid any drift or position change at the output. The mirrors can be positioned in different ways inside the laser, depending on the design constraints of the manufacturer, but the principle is always the same. Manual or motorized mirror mounts can be used to do the operation. The advantage with the motorized mirrors is that you can automate the alignment sequence to avoid opening the laser: it's quicker and you don't risk any particle contamination from opening.

- To realize tuning, some leading laser manufacturers use customized Picomotor actuated pint-sized corner mounts with our Tiny Picomotor actuators, available as vacuum compatible depending on required environment constraints. For instance, Newport 8887 Corner Mounts with 8353 Actuators are commonly used for laser beam ΘxΘy alignment. The high compactness, the degrees of freedom combined with our outstanding customization capabilities for ambient & vacuum use are highly valued by laser manufacturers.

- Motorized ΘxΘy Mirrors can align the laser parallel to the optimal path. If the laser design and embedded features also requires precise beam centering, then additional degrees of freedom are required for the mirror mount. Newport 8081 XYZΘxΘy (Figure 2) Motorized Five-Axis Tilt Aligner, is used for laser alignment and in-tune system by laser manufacturers who are looking for five degrees of freedom, compactness, and extremely high-resolution adjustment (< 30nm) in a compact product.

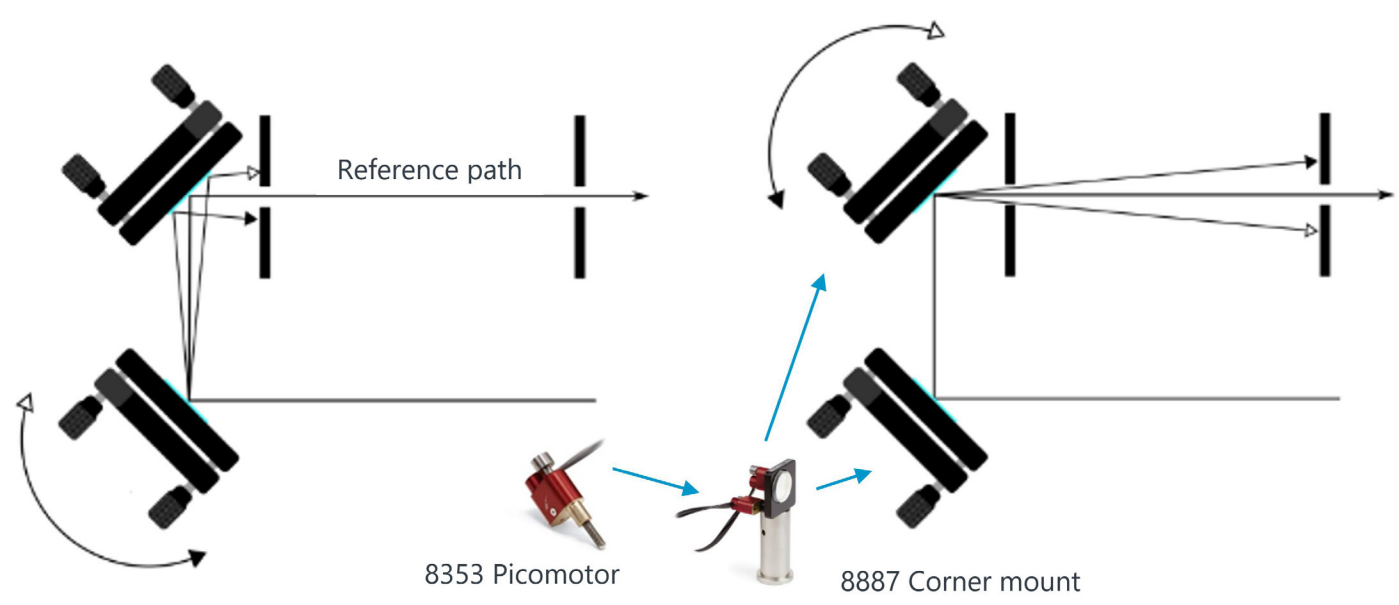


Figure 1: Laser Alignment Optimization

Figure 2: Newport 8081 XYZΘxΘy Motorized Five-Axis Tilt Aligner

Figure 3: CONEX-SAG Super Agilis

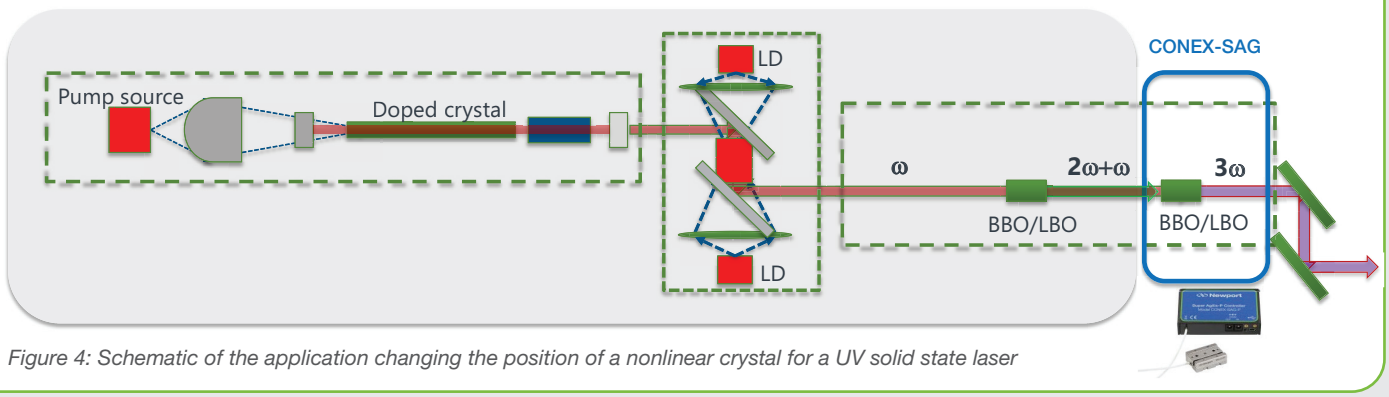


Figure 4: Schematic of the application changing the position of a nonlinear crystal for a UV solid state laser

Two other applications mentioned previously use a Super Agilis stage with a controller:

Figure 4 shows the CONEX-SAG used in a UV laser for shifting the beam spot to a clear (undamaged) area of the BBO/LBO crystal in the laser system.

The laser beam is focused on a non-linear crystal (BBO/LBO) to generate the UV wavelength. After several thousand hours, the crystal surface can degrade, and the user needs to move the laser beam on the crystal to a pristine area to recover the laser properties and restore optimal operation. The incidence of the laser beam remains unchanged as long as the CONEX-SAG (Figure 3) isn't energized and so the system for changing position is very stable. BBO: Beta Barium Borate, LBO: Lithium TriBorate

Figure 5 shows a similar set-up that uses a CONEX controller and a Super Agilis actuator to adjust the pulse width for ultrafast lasers, which is one way to implement a variable pulse compression system in an ultrafast amplifier. The key components involved in pulse length adjustment – the diffraction grating, vertical retroreflector (VRR), and horizontal retroreflector (HRR) – are located in a module shown in the dashed green box.

Laser light entering this module first encounters the diffraction grating. This disperses the different frequency components of the laser pulse spatially, with higher frequencies (shorter wavelengths) being diffracted at larger angles than lower frequencies (longer wavelengths). The beam then encounters the HRR which folds the optical path and sends the beam on to the VRR. The VRR reflects the dispersed beam right back towards the grating.

Moving the HRR changes the relative overall path length that the different frequency components of the pulse travel. Moving the HRR farther from the grating increases the total path length difference between the frequency components. This increases pulse length. Conversely, moving these components closer together reduces the path length difference and shortens the pulse duration.

Because of their compactness, high accuracy and sub-micron step, Newport Super Agilis devices are good candidates for both use cases.

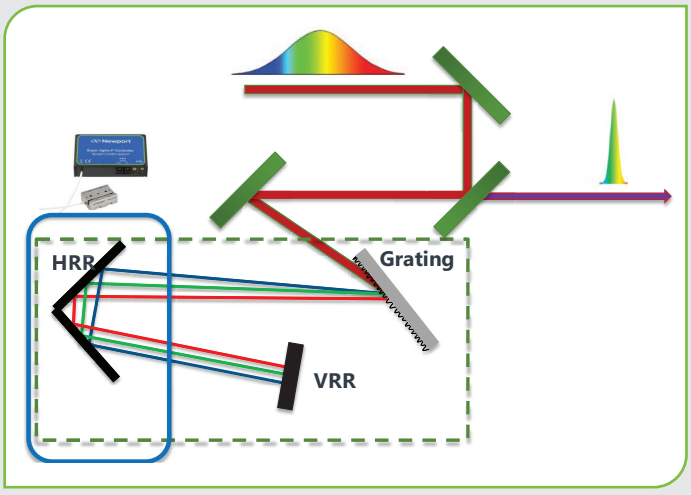


Figure 5: Schematic of the CONEX-SAG is used to adjust the pulse duration for ultrafast lasers. Translation movement delivered by the CONEX-SAG stage on HRR mirror

V. Conclusion

Newport piezo-based nanopositioning and optical mount solutions (Newport or New Focus™ Picomotor, Agilis, CONEX™) are ideal components for demanding laser applications. The product range includes a wide variety of Picomotors, stages, actuators, mirror & lens mounts for alignment control and demanding real-time compensation and adjustments when required.

Newport brand's wide product range allows customers to find the components that fit perfectly into their application (form factor, travel range, mounting, vacuum technology, or closed-loop options availability). All of these are easily controlled with Newport's plug-and-play controllers designed exclusively for these types of actuators. The compactness of the components, their exceptional accuracy, resolution, and stability performance make them very attractive. The standard piezo actuators and Picomotors can be used or customized to perfectly suit specific customer needs and will remain easy to implement and use thanks to the Newport brand's offer of dedicated controllers and accessories.

Piezo Motor Laser Application Note - Support Products

8081: Motorized XYZΘxΘy Tilt Aligner, 3 mm, 8°

The 8081 XYZΘxΘy Motorized Five-Axis Tilt Aligner increases the utility of our popular kinematic stages by motorizing each of the axes. The addition of Picomotor actuators to each stage allows remote high-resolution (<30 nm) adjustment of various combinations of X, Y, Z, Θx, and Θy. Model 8081 five-axis aligners are ideal for positioning modulators or isolators and for coupling light into waveguide devices. Available with metric or SAE tapped holes.

CONEX-SAG-LS48P: High Speed Piezo Linear Stage, 48 mm Travel, Direct Encoder, Integrated Controller

The Super Agilis CONEX-SAG-LS48P is a piezo motor linear stage integrated with a closed-loop piezo motor controller/driver that provides 48 mm travel and up to 10 mm/sec speed. The compact linear stage has a built-in direct read linear encoder enabling high position repeatability, for sample positioning, as an optics inserter, for focusing, etc. The innovation in this encoder technology allows the footprint to be maintained while delivering sub-micron bi-directional repeatability.

The CONEX-SAG-P controller's closed-loop algorithm combined with the direct read linear encoder provides a system bi-directional repeatability of 25 nm. For positional stability, the user can adjust the dead band parameter that stops dithering when the stage is within a set position tolerance.

The CONEX-SAG-LS48P is a very compact and inexpensive single axis motion controller delivered already pre-configured for the stage. The controller is accessible via USB, with options for other serial connections, from an easy-to-use GUI or proprietary solution using an extensive command set.

With a MIM of 25 nm, this stage is perfect fit for high precision applications also needing high speed. Also it is easy to stack stages into a XY configuration without requiring an adapter.

8885: Piezo Mirror Mount, Pint-Sized, Center Mount, 0.5 in. Diameter

The 8885 Picomotor Actuated Pint-Sized Center Mounts eliminate problems usually associated with small systems where there is little room to make adjustments and there is high sensitivity to adjustments by hand. The two Picomotor actuators that allow remote adjustment of

the tip and tilt axes add only 0.5 in. of depth to this 0.5 inch (12.7 mm) diameter mount.

Our Tiny Picomotor actuators allow for an angular resolution of 1.5 µrad, allowing for very small, controlled movements of your optics. The Tiny Picomotor actuator offers the additional advantage of using the integrated knobs for quick, manual adjustment of all axes.

The Picomotor actuator moves when voltage is applied to the piezo, changing its length and in turn moving the jaws which turn the screw. When no power is applied, the actuator does not move. You can feel confident that your mount will stay put, even when you power down your system.

Sapphire seats, optimized spring locations and spring force provides for smooth, reliable motorized adjustment while maintaining a high level of thermal and mechanical stability.

8353-V: Piezo Actuator, Tiny Picomotor

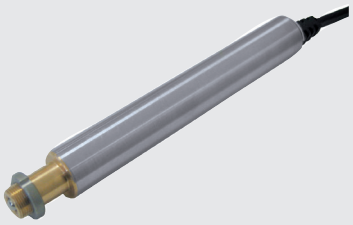
The 8353 Tiny Picomotor actuator is a smaller version of our standard Picomotor actuators. We have improved the design so that it will meet even more of your compact-area needs.

The 8353-V Vacuum Compatible Tiny Picomotor Actuator is designed for environments down to 10^{-6} Torr. It's perfect for moving small optics and stages in your vacuum chambers.

Our Picomotor actuators have a step size of less than 30 nm per step, allowing for very small, controlled movements. Note that the step size for open-loop picomotors varies from step to step and between forward and backward directions, and is directly related to payload – hence, position feedback should be provided by an external signal when operating an open-loop picomotor. For applications requiring absolute position calibration and high repeatability, consider a Closed-Loop Picomotor actuator.

TRA25CC: Motorized Actuator, Miniature, 25 mm Travel, DC Servo Motor

The TRA25CC Miniature DC Servo Actuator provides 25 mm travel in a slightly larger package than the other TRA actuators, while offering a Minimum Incremental Motion of 0.2 µm. It is the recommended choice for motorizing longer travel linear stages and other devices with longer travel range. TRA actuators incorporate an excellent space saving design that allows them to be used with a wide variety of linear stages, mirror mounts, and OEM applications.



TRA actuators offer a similar form-factor as micrometer drives, allowing them to be used to upgrade manual stages with ease.

TRA actuators also feature a hard-coated steel ball tip that minimizes contact surface wear compared to other designs that use regular steel ball tips.

All TRA actuators include integrated optical limit switches. These highly reliable switches not only protect investments from over travel damage, they also provide a method for repeatable referencing/homing, for instance after shut-downs.

DS-122301 Piezo Motor Laser App Note 07/24