Industrial Alignment Innovation:
CyberAligner™ Modular OEM Alignment Workstation
Ideal for cost-effective photonics production and test

Automated alignment applications are among the most challenging in motion control. For example, single-mode fiber pigtailing requires 10-50nm accuracies plus real-time compensation of drift forces. Increasingly high throughput is demanded due to cost-of-ownership and yield pressures.

Currently-available systems fall into a few categories:

- Laboratory-duty instruments with alignment automation capability. Automation is via analog phase demodulation or hill-climbing decision-path methodologies. These mechanisms are usually open-loop.
- Purpose-built industrial process tools configured to perform specific pigtailing, bonding or other narrowly-defined procedures. These tend to be costly and require custom application.
- Integrated multi-axis microrobotic systems specifically designed for photonic packaging automation.
- Stacks of long-travel stages providing many mm of travel with high resolution. These tend to be bulky and costly since the high resolution is provided by long-travel encoders of exceptional capability.

Now, PI introduces F-130 and F-131, a modular, compact family of coarse/fine OEM solutions for industrial-class, high-throughput nanoscale XYZ alignment and positioning (see Figure 1 and Figure 4). This revolutionary concept integrates proven, space-efficient and cost-effective positioners into a versatile and reliable subassembly suitable for a wide variety of industrial production and test applications. It provides sub-µm resolution over an operating volume up to 15x15x15mm plus nanometer-scale resolution/millisecond responsiveness over a 100µm cube. This new solution offers groundbreaking compactness, speed and cost-effectiveness.

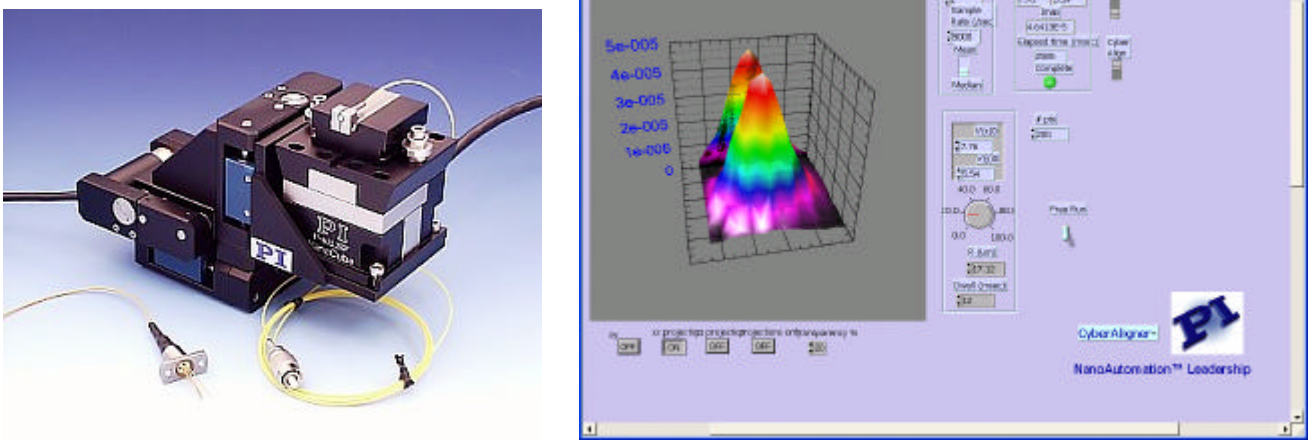

Figure 1. F-130/131 (left) includes a fast, robust XYZ or XY NanoCube™ nanopositioner integrated onto an XYZ stack of high-resolution motorized stages for up to 15mm travel. The combination provides long travel with piezo-class resolution and speed, providing exceptional cost-effectiveness, flexibility and modularity. The CyberAligner™ software (right) is a LabVIEW-based coarse/fine alignment workstation, fully integrable into advanced packaging and characterization applications.

Bridging the Gap: The OEM solution

The F-130/131 open-architecture approach, featured on PI Catalog page 8-18, is based on high-volume, general-purpose nanopositioners from PI's broad line of positioning products:

- A NanoCube XYZ piezo nanopositioning stage is used for fine alignments and tracking.
- In the closed-loop version, strain gauge sensors are integrated for high-bandwidth loop closure, addressing hysteresis and drift.
- An XYZ stack of PI's popular M-110 stages provides long travel positioning. 5mm and 15mm versions are offered. Generally, the open-loop stepper-motor versions of these stages offer the most cost-effective solution for most alignment applications; closed-loop servo-motor versions are also offered. All are provided with integral Hall-effect limit/home switches for repeatable system initialization.
- The result is a high-speed, high-resolution, long-travel assembly with nanometer-scale resolution over a long travel range, but much more compact and much less costly than a stack of stages of commensurate resolution over their entire travel. The combination is compatible with all analog and digital alignment methodologies.

Conceived for Challenging NanoAutomation® Applications

Recognizing that today's production and test applications require not just nanometers, but nanometers in milliseconds™, the F-130/131 architecture is built for round-the-clock throughput:

- The nanopositioning stage uses *no bearings*. Bearings are susceptible to cage creep and nonreproducible stiction in the sort of rapid, repetitive actuations typical of packaging and alignment applications.
- The stages require *no scheduled maintenance*.
- The *flat-topped actuation platform* is compatible with a variety of fixturing and clamping devices from PI and partner companies, including SD Instruments' manual and automated tweezers.

Versatile CyberAligner™ Software Automates Alignment, Profiling

While F-130/131 is compatible with any alignment methodology you might wish to use, a valuable tool in Polytec PI's arsenal of OEM NanoAutomation solutions is the CyberAligner™ Modular Alignment Engine, a comprehensive software package with high-throughput alignment automation and exquisite 2D profiling capabilities. CyberAligner is an object-oriented set of software modules which perform rapid nanoscale positioning, synchronized with metrology. CyberAligner is based on LabVIEW 6i for open support of a wide variety of metrology instruments and a wealth of analytical and connectivity options. CyberAligner is compatible with many PI NanoAutomation mechanisms in addition to the NanoCube.

The CyberAligner software offers several modes, all readily accessible from a mouse-driven pushbutton PC interface (see Figure 2):

- Manual positioning, automatic move-to-position and initialization routines are available at the click of the mouse.
- A novel double-spiral scan of the motorized stages finds first light. Unlike most spiral-scan implementation, this performs a second spiral at the first hint of coupling. This greatly speeds up completion of the first-light scan, as one or more entire loops around the initial spiral are eliminated. This also minimizes overall transverse motion— important in blind-hole packaging applications.
- A highly speed-optimized raster scan is available for fine acquisition, characterization and centering of the devices; this is described in more detail below.

Figure 2. The CyberAligner workstation software is as modular as the hardware. Constructed in LabVIEW 6i, it

includes a variety of alignment and positioning functions which are accessible by a mouse-click.

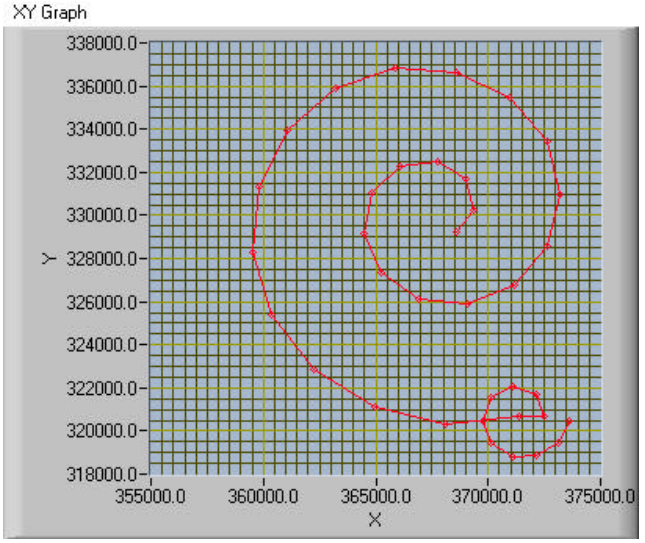

Figure 3. CyberAligner's unique double-spiral first-light scan minimizes both execution time and overall transverse motion. A conventional spiral scan is performed until the first hint of coupling is detected, then a second spiral is automatically performed about that point. This greatly improves alignment speed by eliminating one or more entire loops of the first spiral. The figure shows the path of the coarse-positioning stage from initiation of the first-light search through initial acquisition and final achievement of the user's desired threshold. From here, nanoscale fine-alignment can proceed.

Novel High-Speed Raster Fine-Alignment

Most automated alignment methodologies utilize hill-climbing or gradient-search techniques to fine-tune the optimum orientation of the devices under test. This is necessitated by the comparatively slow speed of typical motion hardware. However, most alignment algorithms can lock-on to local maxima. CyberAligner leverages F-130/131's high-bandwidth nano-actuation to map the entire scan field— practically eliminating the likelihood of lock-on to local maxima. The map itself provides valuable characterization of the coupling cross-section which can provide exquisite spatial and power resolution (Figure 4).

Figure 1shows a CyberAligner profile of butt-coupled single-mode fibers. The Z axis (for the metrology chosen in this particular setup) is in mW. A user-selectable projection of the X-Z plane is shown. CyberAligner's 3D graphics are freely rotatable by the user by clicking and dragging the plot with the mouse; this is highly useful for inspection of features. Statistics for this application example:

Devices:	Butt-coupled 4µm core SM fibers
Data points:	900
Range:	8x8µm
Motion Dwell	1msec (software-settable)
Total Execution Time:	2.6 seconds inc. graphics
PC:	Pentium II, 266MHz, Windows 98, 64Mb, National Instruments analog I/O card

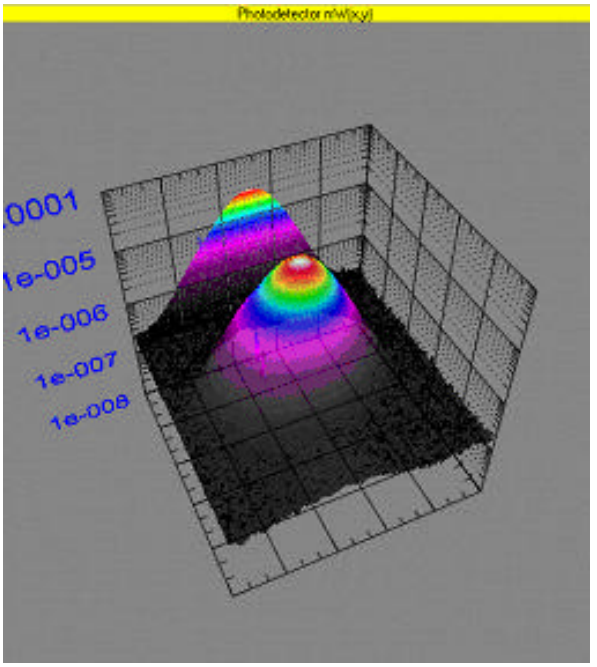

Figure 4. Actual CyberAligner scan data: 30x30mm coupling-cross-section profile of butt-coupled SM fibers @630nm ?. In this implementation, optical power is provided by a Small Planet Photonics optical power meter, providing NIST-traceable accuracy.

If High Throughput Motions Cause Structural Ringing— Mach Stops It!

The Nanocube is an extraordinarily fast positioner, as the sub-3-second execution of the profile shown in Figure 1attests. In applications where even faster actuation of is desired, the rapid motions can sometimes cause recoil-generated ringing of their load, fixturing and adjacent components. Such ringing can take hundreds of milliseconds to damp out.

Conventional wisdom suggests that there is nothing that can be done about these resonant reactions, since they occur outside any servo loop and cannot be observed by the controls. However, PI's optional Mach™ Throughput Coprocessor™ implements the patented Input Shaping™ feedforward algorithm to nullify resonances *before* they start, rather than waiting for them to damp out (turn into heat). The result: the fastest possible motion, with virtually instant settling, as shown in actual vibrometer testing in Figure 5.

Mach is easy to set up for a particular OEM application and robust to dynamical changes in the setup. It requires no change to the system software, application, physical setup or servo parameters. It is available both as an external upgrade to existing PI controllers and as an internal option for our latest generation units. It eliminates unwanted motion-driven resonances and ringing in step-mode and continuous-motion (scanning) applications. In particular, Mach eliminates any resonant reaction of devices mounted on the F-130/131, its platform, and sensitive adjacent optomechanical componentry to improve throughput and resolution in especially high-throughput applications.

For more information, including applications examples, contact Polytec PI for a specific Tech Note on the Mach Throughput Coprocessor.

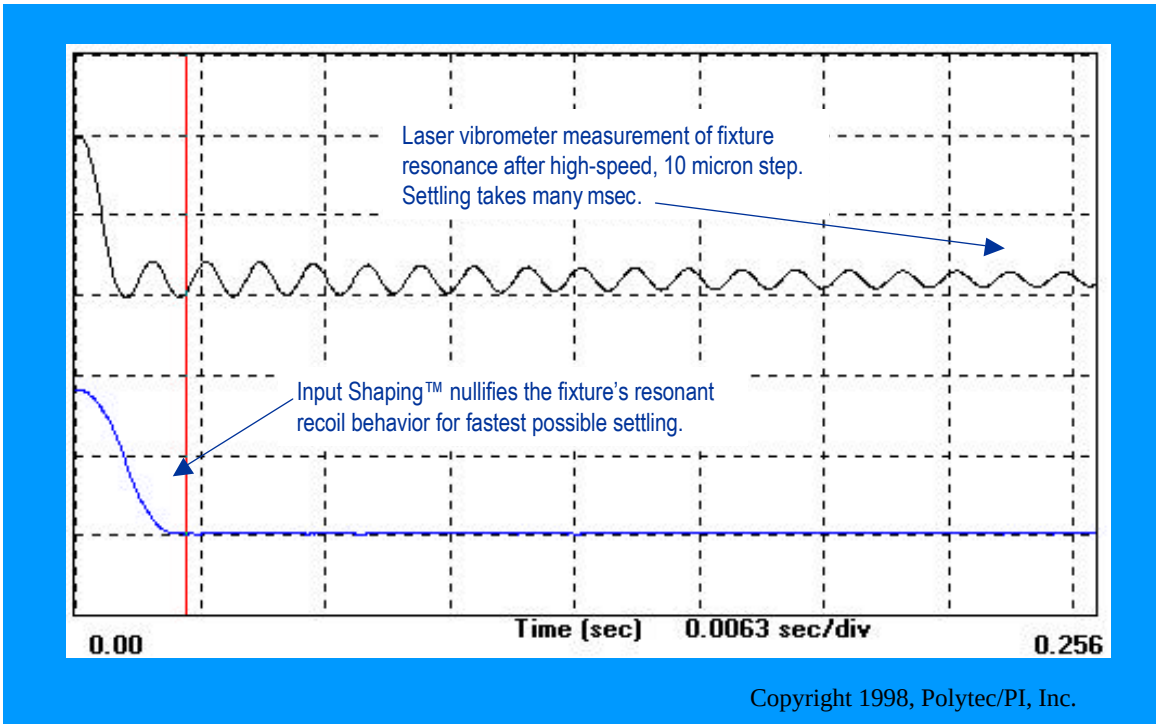

Figure 5. Mach™ Throughput Coprocessor eliminates the recoil-driven resonant reaction of loads and neighboring componentry in applications where the fastest possible nanopositioning is desired. Top: Vibrometer reveals the resonant behavior of a fixture when the stage is stepped. Bottom: Same fixture, same step, with Mach. The structural ringing is eliminated.

Configurations

F-130/131 may be implemented in a variety of configurations to match the broad spectrum of OEM scanning and photonics-packaging application needs and budgets. Open- and closed-loop motorized and nanopositioning stages are offered, with various different travel ranges for the coarse stages, and ball-screw versions for especially intensive 24/7 automation applications.

There is a spectrum of controls options as well. A particularly cost-effective approach includes:

- Open loop F-130/131 stepper motor coarse positioning stages, 5 or 15mm travel, with NanoCube
- Analog PZT controls such as PI's E-5xx series; Mach™ Throughput Coprocessor™ optional
- National Instruments 7344 motion controller card (PCI bus)
- National Instruments 7604 driver/interface (stepper) or PI C-809.40 driver/interface (servo)
- A Small Planet Photonics power meter (recommended for its >10kHz analog bandwidth and NIST-traceable accuracy)

This is a single-card PC solution which leverages the analog utility outputs of the 7344 controller when used with stepper-motor stages. An equivalent PXI-bus configuration is also available with an embedded PC running Windows or a real-time operating system.

Other variations—including systems with longer-travel coarse-positioning stages from PI's catalog, or alternate nanopositioning mechanisms—may be readily configured as well. Consult with your Polytec PI applications engineer.

Conclusion

This Tech Note describes several new products for high-throughput, automated micro-alignment and profiling applications:

- F-130/131 is a unique coarse/fine motion subassembly providing 100µm XYZ nanopositioning range and 5 or 15mm of submicron-precision stepper- or servo-motor coarse positioning. Compact, modular and robust, it is intended for industrial applications in the realm of photonics packaging automation.
- CyberAligner is a versatile software tool for automating profiling and alignment, offering novel, high-throughput first-light and fine-alignment automation capabilities.
- The optional Mach Throughput Coprocessor can improve overall throughput by eliminating settling time: rapid actuation of the nanopositioner can cause ringing of components throughout the assembly in some applications. Mach eliminates this.

Together, these three technologies facilitate a broad array of challenging applications requiring a combination of nanometer-scale precisions, automated alignment and high throughput plus compact size, low cost, and modular flexibility.

Resources:

Polytec PI Web catalog, including tutorials
Micro- and Nano-positioning equipment
http://www.polytecpi.com

National Instruments
Data acquisition and motion controller cards
http://www.ni.com

Small Planet Photonics
High-speed optical power meters
http://www.smallplanetphotonics.com

SD Instruments
Fiber grippers, adaptors and fixtures
http://www.sd-instruments.com