DRIVING FUTURE TECHNOLOGIES

High-Precision Motion and Control Solutions for Laser and Photonics Applications

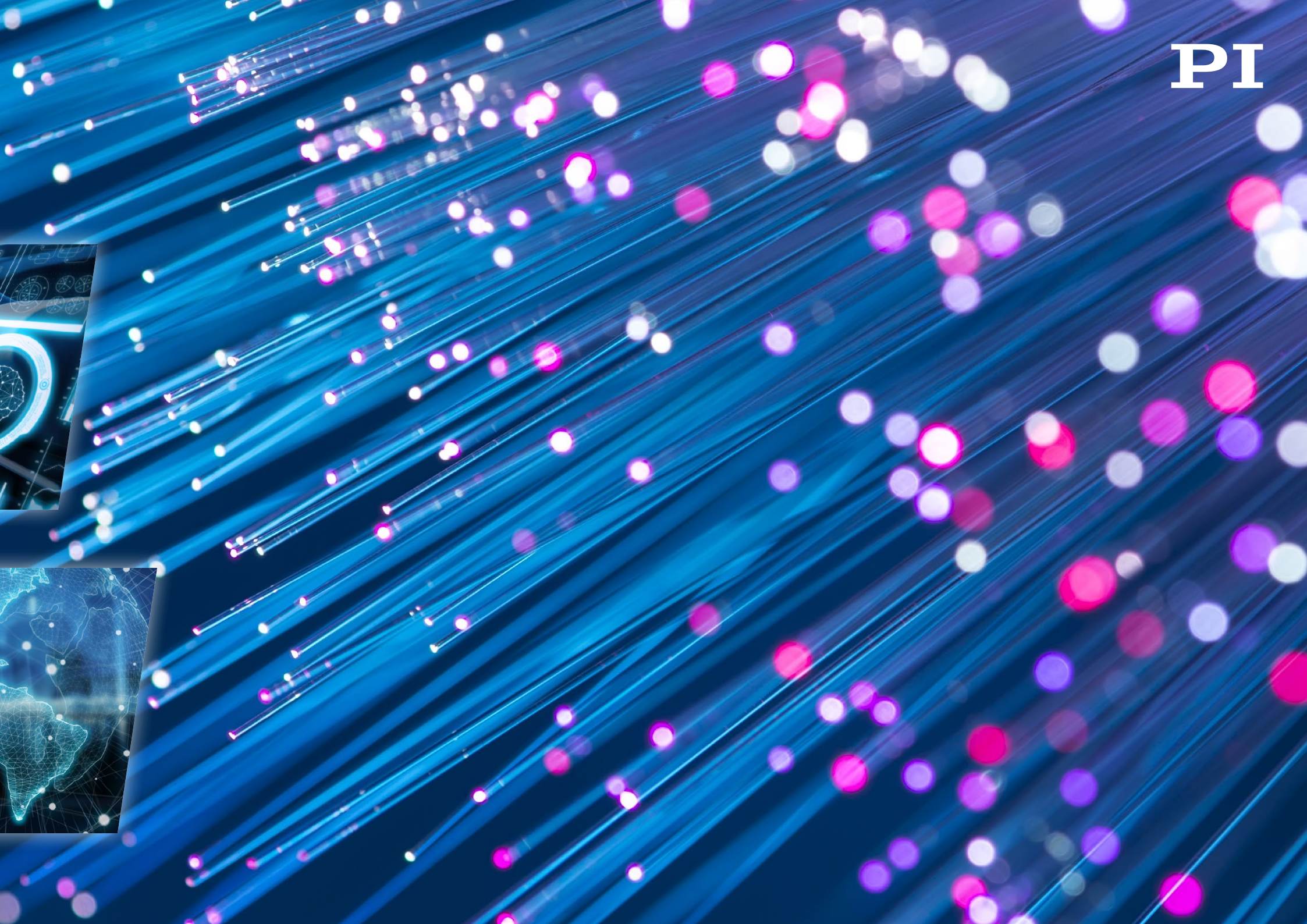
High-Precision Motion and Control Solutions for Laser and Photonics Applications

Light is one of the most important drivers of innovation in production, communication, illumination, energy, and health. It enables optimizing manufacturing processes and quality control, transmitting data and information at extreme speeds, or developing better medical diagnostics and therapies.

In many of these areas, high-precision, fast, and reliable positioning solutions play a key role in maximizing the potential of optical technologies. For example, in synchronizing the motion control of workpieces and lasers, in aligning optics and samples, in coupling components and fibers, or in keeping laser beams on track.

PI's wide range of technologies and many years of experience in precision positioning puts them in an excellent position to address the specific needs of various laser and photonics applications. For example, laser drilling of micro holes, laser seam welding of electronic housings, separation of chips from a wafer and wafer inspection, and characterization and packaging of light emitting devices.

To drive future technologies, PI supports customers from all around the world with motion solutions so they can get the required performance from their processes and machines. PI's solutions range from single components to complex multi-axis solutions, including controllers, drives, and application-specific firmware and software.



Seam Sealing of Electronic Packages Using Pulsed Laser Sources

Easy Synchronization of the Laser to the Part Profile

To protect sensitive electronic components from contaminants seeping in and to ensure safe and reliable operation, the components' housing must be sealed hermetically. Using a laser source as a tool provides high welding speeds and produces fine welding seams with narrow welding radiuses. The advantage of precision laser welding is the contactless application of the laser's energy, which avoids stressing the housing either thermally or mechanically. For example, to create the welding seam, the package to be welded is moved under a pulsed laser source causing the laser spots to overlap each other. This is ideal when the welding process is relatively simple, and the laser spot size is proportionate to the welding width. For a high welding quality, the size and spacing of the laser pulse overlap must remain constant; even at high speeds, and with complex geometries. PI's motion solutions enable synchronization of the laser pulse overlaps and energy in line with the defined motion path.

1 Z Axis – Precise Vertical Motion of the Laser Head

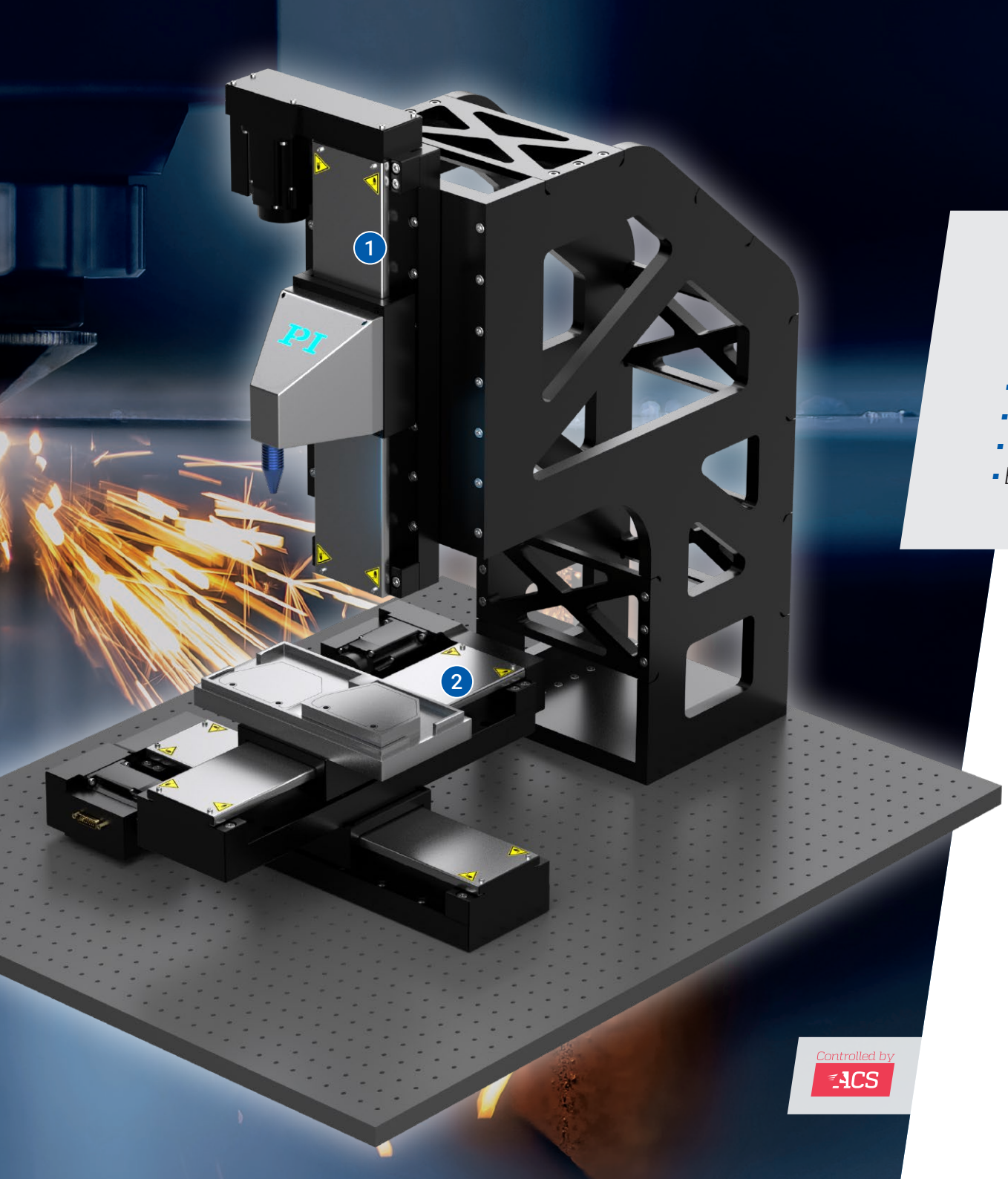
- Precision ball screw linear stage with servo motor and holding brake for reliable operation under high loads
- Absolute encoders avoid workpiece collisions
- Folded drivetrain reduces installation space
- Economically priced with fast delivery

>> L-812 High-Load Linear Stage

2 XY Axis – Repeatable Motion of the Workpiece

- Servo motor-driven ball screw linear stages for high speed and precision
- Absolute encoders avoid referencing and ensure operational safety
- Low XY profile and folded drivetrain reduce installation space
- XY drag chain cable management protects during processing and prolongs lifetime

>> L-812 High-Load Linear Stage



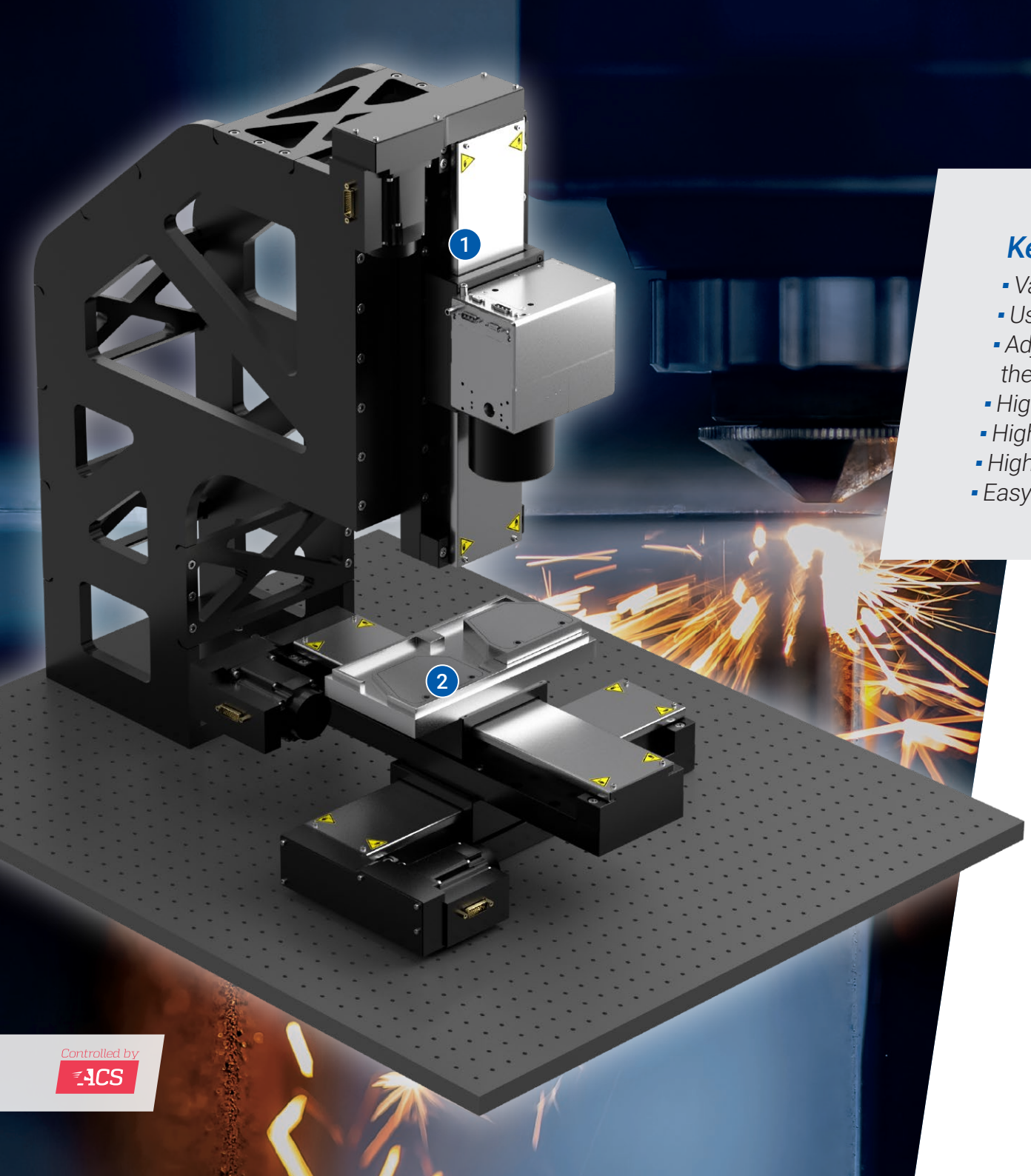
Key Features of the Motion Solution

- *High repeatable sealing process*
- *Highly accurate welding path*
- *Consistent welding quality*
- *Highly configurable welding path*
- *High throughput*
- *Easy laser integration*

Flexible and Easy Automation Control

- EtherCAT® motion control and drive modules provide open network connectivity
- Laser control interface synchronizes the laser beam to the motion path for high-accuracy welding
- Extensive programming environment and support for higher level languages
- Autofocus capabilities of the controller for dynamic focus adjustment
- Look-ahead capability adjusts velocity to maintain accuracy
- Easy programming of motion path including G-Code
- Flexible CAD-to-motion import

>> SPC CAD/CAM Software



Key Features of the Motion Solution

- *Variable seam width control*
- *Usage of fine spot size lasers*
- *Adjustable process control to shape the wobble pattern and frequency*
- *Highly accurate welding path*
- *High welding quality*
- *High throughput*
- *Easy scanner integration*

Controlled by ACS

Flexible and Easy Automation Control

- EtherCAT® motion control and drive modules provide open network connectivity
- Galvo integration options
- Extensive programming environment and support for higher level languages
- Autofocus capabilities of the controller for dynamic focus adjustment
- Look-ahead capability adjusts velocity to maintain accuracy
- Easy programming of motion path including G-Code
- Flexible CAD-to-motion import

>> SPC CAD/CAM Software

Laser Seam Welding of Electronic Packages Using Galvo Scanners

Enhanced Control of Laser Position

For the safe and reliable operation of sensitive electronic components or assemblies, the components' housing must be sealed hermetically to protect the microsystem from damage caused by contaminants seeping in. Using lasers for seam formation enables high welding speeds, as well as fine welding seams with narrow welding radiuses. Laser welding also avoids stressing the housing either thermally or mechanically. One of the methods used in laser seam welding is to move the workpiece to be welded under a laser galvo scanner head. The galvo scanner provides numerous additional control features, for example, expanding the laser source's effective fine spot size to the seam width, laying a complex welding pattern over the motion path to create high-quality welds, increasing throughput, and taking advantage of higher power laser sources. To help unleash the full potential of galvo scanners for laser seam welding, PI offers high-precision motion control solutions, including special software to simplify integrating galvo scanners and laser devices into motion platforms.

1 Z Axis – Control of Galvo Scanner's Vertical Height to Maintain Laser Spot Size

- Precision ball screw linear stage with servo motor and holding brake for reliable operation under high loads
- Absolute encoders avoid workpiece collisions
- Folded drivetrain reduces installation space
- Extensive mounting options
- Economically priced with fast delivery

>> L-812 High-Load Linear Stage

2 XY Axis – Repeatable Motion of the Workpiece

- Servo motor-driven ball screw linear stages for high speed and precision
- Absolute encoders avoid referencing and ensure safety during operation
- Low XY profile and folded drivetrain reduce installation space
- XY drag chain cable management protects during processing and prolongs lifetime

>> L-812 High-Load Linear Stage

Laser Drilling of High-Density Micro Holes

Highly Controlled Hole Taper

Meeting the demands of various industries from medical device to electronics manufacturing it may be necessary to create numerous and dense areas of highly precise and accurately placed micro holes. Smaller diameters can make the mechanical drilling process much more difficult because of the risk of breakage and drill wander. Laser drilling overcomes these problems due to the fine laser beam focusing equal to, or less than the hole diameter required. Additionally, it is a contactless process, preventing any breakages. The challenges in laser drilling are many and include controlling the shape of the taper from entry to exit to achieve high aspects. This depends on controlling the focus as the beam moves through the surface of the material and becomes more difficult the thicker the surface. It may also be necessary to drill thousands of holes with the demand for smaller diameters, requiring smaller laser spot sizes. Other factors include beam shaping and careful selection of the laser wavelength, as well as ensuring that the motion system can provide precise placement and hole accuracy over a large area.

1 Z Axis – Reliable Laser Height Control

- High-precision ball screw linear stage with servo motor and holding brake for reliable operation under high loads
- Absolute encoders for avoiding collisions
- Robust industrial IP65 connectors for flexible cable exit
- Side seal and hard cover to protect against particles

>> L-417 High-Load Linear Stage

2 Z Axis – Laser Focusing for Taper and Cross Section Control

- Voice coil direct drive motor for friction-free operation, high scan frequencies, and fast step-and-settle
- Integrated linear encoders for accurate position feedback
- Adjustable weight force compensation for safe operation
- Easy integration due to flexible mounting options

>> V-308 Voice Coil PIFOC® Focus Drive

3 XY Axis – Positioning of the Workpiece over Long Travel Ranges

- High-dynamic ironless linear motors for fast and precise motion
- Reference edge to ease the alignment in the machine
- Connector for purge air, side seal and hard cover to protect against particles
- Absolute encoders avoid referencing and ensure safety during operation

>> V-417 High-Load Linear Stage

4 XY Axis – Fine-Positioning of the Workpiece

- Piezo-based XY scanner for high-dynamic and nanometer-precise positioning
- Parallel-kinematic design for same dynamics in X and Y direction
- High guiding accuracy due to zero-play flexure guides
- Subnanometer resolution with long-term stability
- Fast ms settling times
- High tracking accuracy in the nanometer range

>> P-527 Multi-Axis Piezo Scanner

Key Features of the Motion Solution

- *High-precision feature shape*
- *Increased hole density*
- *Precise taper control*
- *Consistent, clean and fast drilling process*
- *High throughput*
- *Easy laser integration*

Flexible and Easy Automation Control

- EtherCAT® motion control and drive modules provide open network connectivity
- Profile generation via EtherCAT® or triggering of predefined drilling profiles
- Laser pulse control via EtherCAT® or analog power output
- Servo control for fast step-and-settle and for disturbance rejection
- Ability to add fast piezo control for improved performance for legacy systems

>> E-727 Digital Piezo Controller

Wafer Stealth Dicing

Accurate Formation of the Modified Layer

In the production of chips, it is necessary to separate the individual dies from the wafer. In this process, quality and precision are crucial for all further post-fab operations. Laser dicing has therefore become the preferred technology. One variant is the so-called stealth laser dicing (SLD). This involves creating a modified layer within the wafer by focusing a laser below the surface, and then using a tape expander to separate the chips. Typical challenges faced by this type of wafer dicing application are to use systems that do not introduce any additional contamination risks to the wafer, to be able to accurately position the modified layer onto both XY axes to enable the narrowest possible streets, and to maintain the focus within the wafer and track wafer distortions. At the same time, the highest possible scanning speed is necessary to ensure high throughput. As requirements continue to increase, stealth laser dicing is becoming the first choice for high-volume, MEMS, or smaller and more complex dies. Accordingly, laser-dicing processes also demand motion systems offering both high accuracy and a high level of straightness at high velocities.

1 Z Axis – High-Dynamic Laser Focus Control

- Wear-free, lever-amplified piezo drives for 24/7 operations without particle generation
- Mechanical design with high stiffness and high resonant frequencies provide high dynamics and short settling times and allows high payload
- Up to 800 µm travel range to match the wafer thickness
- Fine positioning with subnanometer resolution

>> P-725 PIFOC® Objective Scanner

2 θX/θY/Z Axis – High-Precision Wafer Alignment and Positioning

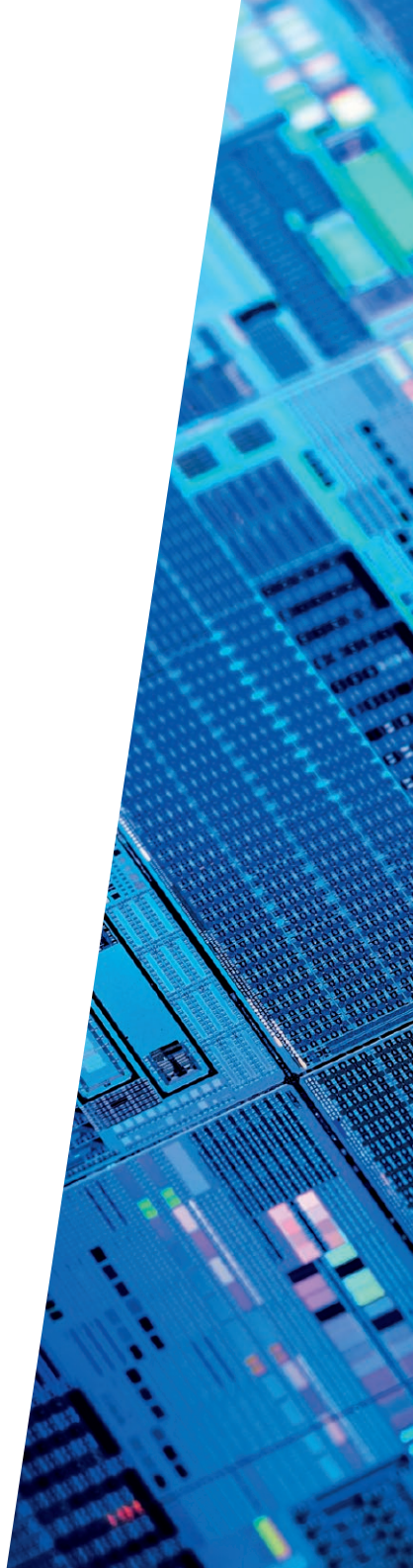
- Parallel-kinematic design for wafer adjustment and offset corrections in three dimensions
- Direct drive linear motor with air bearings ensures high precision
- Frictionless design with minimal hysteresis provides high repeatability and adjustments in the nanometer range
- Low-profile design for easy integration
- Maintenance-free with long lifetime in 24/7 operations

>> A-523 Z Tip/Tilt Stage

3 XY Axis – High-Dynamic Wafer Scanning Motion

- Air bearing planar scanner with ironless linear motors for high, cog-free scanning speed and fast stepping and settling
- Wear-free design allows 24/7 high duty cycle operations with minimal runout errors and nanometer straightness and flatness
- High-resolution absolute linear encoder option for fast startup, reliability, and safety
- Low profile, monolithic design allows easy integration to system level solutions for compact installation space
- Wide carriage insures increased stiffness

>> A-311 Air Bearing Planar Scanner



Key Features of the Motion Solution

- *High yield in chip singulation*
- *Contamination-free processing*
- *Creation of narrow street width*
- *High throughput*
- *No damaging of front and back surfaces*
- *High-dynamic creation of a uniform layer modulation along predefined cutting lines*
- *Advanced laser control*

Advanced Automation Control

- EtherCAT® motion control and drive modules provide open network connectivity
- Laser control interface synchronizes the fixed laser beam to the motion path for high-accuracy cutting
- NanoPWM™ drive technology reduces tracking error and optimizes velocity
- Integrated piezo height axes control synchronized to wafer scan axes
- Advanced algorithms provide fast step-and-settling, high in-position stability, and exceptional constant scanning velocity

>> ServoBoost™

Controlled by ACS

Key Features of the Motion Solution

- *Defect and edge placement error (EPE) inspections*
- *Highly adaptive surface inspection*
- *High throughput*
- *Reduced dynamic errors and optimized focusing time*
- *High reliability at high duty cycles*
- *Reduced cost of ownership*
- *Secured yield*

Advanced Automation Control

- EtherCAT® motion control and drive modules provide open network connectivity
  >> Controller & Drives
- Advanced algorithms provide fast step-and-settling, high in-position stability, and exceptional constant scanning velocity
  >> ServoBoost™
- Fast digital interchange to trigger fast focus on Z axes

Wafer Inspection and Metrology

Fast Scanning and Characterization at Wafer Level

The entire chip manufacturing process consists of 400 to 800 production steps. At all critical points in the manufacturing process, inspection processes are essential to ensure the high quality and reliability of the final products. Additionally, they help secure a defined yield of the cost-intensive chip production. Moreover, with each node, the inspection process becomes more challenging and costly. Nowadays, defect tolerance is increasingly low due to process shrinks, smaller features, design complexities, and the integration of heterogeneous components at wafer level. For this reason, and to reduce costs, today's optical inspection tools must detect defects in the nanometer range, enabling damaged structures to be removed from the process at an early stage. These tools often work in scanning modes where a specific position must be identified and subsequently approached with high precision, or for applications where it is necessary to follow a trajectory for processing steps. Within our product portfolio, PI provides the integrated solution to support both substrate carriers and objective assembly.

1 Z Axis – High-Dynamic Laser Focus Control

- Wear-free, lever-amplified piezo drives for 24/7 operations without particle generation
- Mechanical design with high stiffness and high resonant frequencies provide high dynamics and short settling times and allows high payload of larger objectives
- Up to 800 µm travel range
- Fine positioning with subnanometer resolution

>> P-725 PIFOC® Objective Scanner

2 θX/θY/Z Axis – High-Precision Wafer Alignment and Positioning

- Parallel-kinematic design for wafer adjustment and offset corrections in three dimensions
- Direct drive linear motor with air bearings for high precision
- Frictionless design with minimal hysteresis provides high repeatability and adjustments in the nanometer range
- Low-profile design for easy integration
- Maintenance-free with long lifetime in 24/7 operations

>> A-523 Z Tip/Tilt Stage

3 XY Axis – Wafer Step-and-Scan Motion

- Air bearing planar scanner with ironless linear motors for high, cog-free scanning speed and fast stepping and settling times
- Wear-free design allows 24/7 high duty cycle operations with minimal runout errors and nanometer straightness and flatness
- High-resolution absolute linear encoder option for fast startup, reliability, and safety
- Low profile, monolithic design allows easy integration to system level solutions for compact installation space
- Wide carriage ensures increased stiffness

>> A-311 Air Bearing Planar Scanner

Characterization of Light Emitting Devices

Fast Active Alignment

The classic application focus of Optical Coherence Tomography (OCT) is the medical field of ophthalmology. However, today, OCT also gets considered for applications in industrial environments such as printed circuit board (PCB) layer diagnostics, and material surface analysis. Modern OCT solutions demand light sources with a high spectral bandwidth and a long coherence length. Super luminescent emitting diodes (SLED) and swept laser sources (SLS) are both light sources that need to fulfill increasingly demanding customer requirements. For this reason, SLED and SLS are becoming more expensive, meaning that a quality check is economically unavoidable before completing the next step: inclusion into a butterfly package. Fast and synchronized testing on-the-fly can be realized with PI's Fast Multi-Channel Photonics Alignment (FMPA) systems. Automated area scans allow fast and reliable high-resolution emission profile analysis. Additionally, the intelligent gradient search algorithm can track the position of the optimum of any figure of merit for example light intensity for hours.

1 XYZ/ θX θY θZ – Automatic Submicron Alignment of the Optical Fiber

- Parallel-kinematic hexapod for fast alignment over long travel ranges in six degrees of freedom
- High stiffness of the mechanical design provides high dynamics and short settling times
- Freely definable center of rotation addresses geometrical offsets
- Position sensors ensure high accuracy and operational reliability
- Compact design for space saving integration

>> H-811 6-Axis Miniature Hexapod

2 XYZ Axis – Automatic Nanometer Alignment of the Optical Fiber

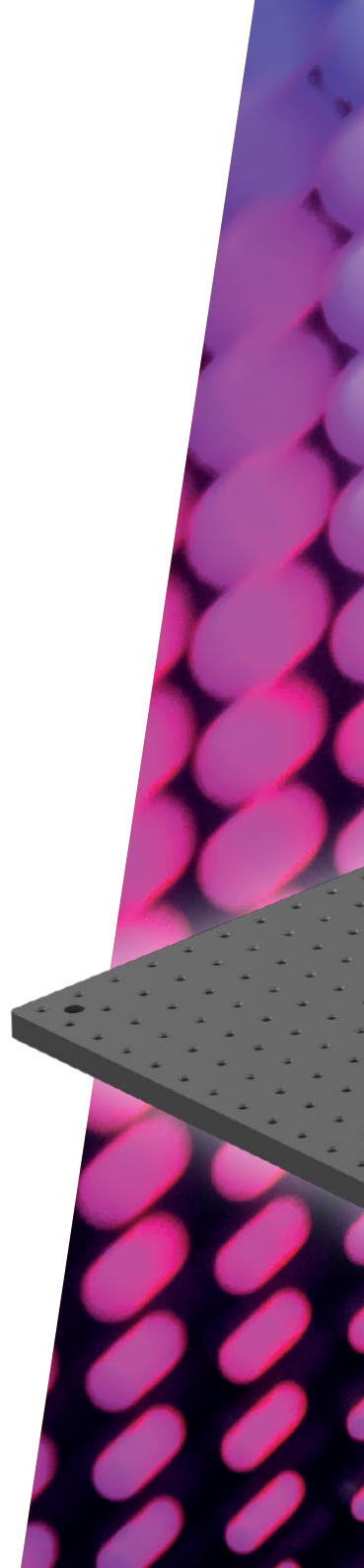
- Parallel-kinematic piezo system for high stiffness in all spatial directions
- Mechanical design provides scanning frequencies of up to 100 Hz and fast tracking
- Zero-play flexure guides for high guiding accuracy without any wear or particle generation
- Integrated sensors offer excellent linearity of motion, and long-term stability
- All-ceramic insulated piezo actuators for outstanding lifetime

>> P-616 NanoCube® Nanopositioner

3 θZ Axis – Reliable and Scalable Placing of the Optical Components

- Highly accurate and repeatable 360° rotation without backlash
- High velocities and accelerations due to magnetic direct drives
- Ironless linear motors provide smooth and precise operation without cogging
- Low profile design for space saving integration

>> V-610 Compact PIMag® Rotation Stage



Key Features of the Alignment Solution

- *Proven and award-winning technology*
- *99% reduction of characterization time*
- *Reduced systematic error through alignment to the optimum of the figure of merit*
- *Reliable tracking during long-term process steps*
- *Scalable for fab-class testing*
- *Lowest cost of ownership*
- *Optimization of any figure-of-merit*

User-Friendly and Flexible Automation Control

- EtherCAT® interfaces enable fast integration into high-throughput industrial systems
- High-performance controllers automate built-in scans and optimizations with millisecond responsiveness
- Proprietary firmware for fast fiber alignment based on area scanning algorithms for first light detection and gradient search for peak coupling
- Fast application development on all common operating systems as well as programming languages including MATLAB , Python, C# and NI LabVIEW
- Quick start-up and ease of use with PIMicroMove software

>> C-887 Hexapod Motion Controller with EtherCAT®
>> E-712 Digital Piezo Controller

Key Features of the Alignment Solution

- *Proven and award-winning technology*
- *Simultaneous alignment across multiple channels, I/Os, elements, and degrees of freedom*
- *Parallel processing allows 100 times the speed of serial operation*
- *99% reduction of alignment-time cost*
- *Scalable for fab-class assembly*
- *Lowest cost of ownership*
- *Reliable tracking during long-term process steps*
- *Optimization of any figure-of-merit*

User-Friendly and Flexible Automation Control

- EtherCAT® interfaces enable fast integration into high-throughput industrial systems
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>> E-712 Digital Piezo Controller

Assembly and Packaging of Photonic Devices

Fast Multi-Channel Active Alignment

Modern passive optical networks (PON) rely on passive optical components that can split or combine light signals coming from high-power light sources. Replacing active components with passive components provides significant cost savings by eliminating the need to power and service active components in the transmission loop. However, to ensure error-free operation, only minimal optical alignment losses are permitted in any point-to-multipoint link within a high-performance PON. This also applies to butterfly-packaged active optical devices that contain a light source, gratings, filters and µlenses. The challenge in both situations is to align the light source and the optics optimally as fast as possible. Fast parallel alignment of several optical components can be realized with PI's Fast Multi-Channel Photonics Alignment (FMPA) systems. Automated area scans allow fast and reliable first light detection. An intelligent gradient search algorithm can optimally align each of the components simultaneously. Additionally, during long process steps like the curing of glue, gradient search algorithm can actively correct the position resulting in devices with extraordinary performance.

1 XYZ/ θX θY θZ – Automatic Submicron Alignment of Fiber and Fiber Arrays to Optical Components

- Parallel-kinematic hexapod for fast alignment over long travel ranges in six degrees of freedom
- High stiffness of the mechanical design provides high dynamics and short settling times
- Freely definable center of rotation allows flexible alignment for edge coupling
- Position sensors ensure high accuracy and operational reliability
- Compact design for space saving integration

>> H-811 6-Axis Miniature Hexapod

2 XYZ Axis – Automatic Nanometer Alignment of Fibers to Optical Components

- Parallel-kinematic piezo system for high stiffness in all spatial directions
- Mechanical design provides scanning frequencies of up to 100 Hz and fast tracking
- Zero-play flexure guides for high guiding accuracy without any wear or particle generation
- Integrated sensors offer excellent linearity of motion, and long-term stability
- All-ceramic insulated piezo actuators for outstanding lifetime

>> P-616 NanoCube® Nanopositioner

3 θZ Axis – Reliable and Scalable Placing of the Optical Components

- Highly accurate and repeatable 360° rotation without backlash
- High velocities and accelerations due to magnetic direct drives
- Ironless linear motors provide smooth and precise operation without cogging
- Low profile design for space saving integration

>> V-610 Compact PIMag® Rotation Stage

The PI Group

Physik Instrumente is market leader for high-precision positioning solutions and piezo technology applications in the semiconductor industry, life sciences, photonics, and industrial automation. Working closely with customers around the world, PI has been pushing technological boundaries and developing solutions to drive future market trends for more than 50 years. Over 400 patents underline the company's claim to innovation. PI develops, manufactures, and qualifies their entire core technology: From piezo elements and motors as well as magnetic direct drives through air bearings, magnetic and flexure guides to sensors, controllers, and software. With nine production sites and 16 sales and service offices in Europe, North America and Asia, the PI Group is well positioned in all key technology regions. PI is privately owned with a healthy growth and more than 1400 employees worldwide.

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