

Wafer Positioning and Bonding for Advanced Packaging

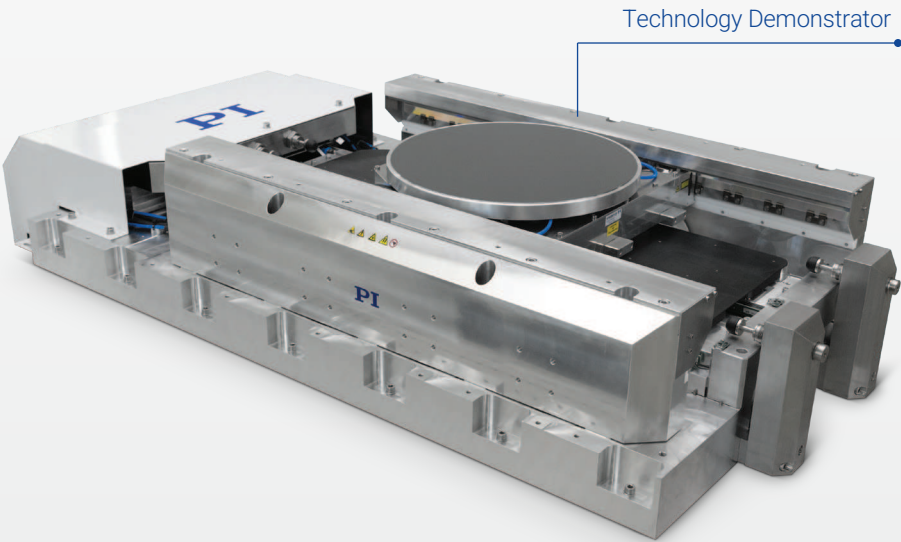


6DoF Positioning and Force Control for High-Throughput Packaging

Advanced packaging demands positioning resolution, dynamic performance, and controlled process forces in a single motion system. Built on magnetic levitation, this demonstrator combines long-travel multi-axis positioning, nanometer-class stability, and integrated force control in one contact-free stage, ready to scale toward high-throughput bonding.

Key MagLev Advantages

- ✓ **6DoF Control** — Precise control in multiple axes
- ✓ **Force Control** — Precise control of process forces
- ✓ **Low Moving Mass** — High dynamics and short settling
- ✓ **Contact-Free Operation** — No lubricants, wear, or particle generation



Dynamics	Alignment Capability	In-Position Stability	Force Controlled Bonding Capability	Repeatability	Z-Stroke Crosstalk
Acceleration: 2* ... 6 g Velocity: 400* ... 2000 mm/s	X: 400 mm* Y: ±200 µm* θZ: ±1 mrad* θXY: ±0.5 mrad*	Z: <2 nm* θXYZ: <20 nrad*	Z: ±200* ... 1000 µm >100 N* process force mN* resolution**	Double-digit nanometer*	XZ/YZ: single-digit nanometer crosstalk over full Z stroke

* Asterisked values represent the performance of the demonstrator shown; additional values indicate achievable performance with different system configurations.
** With integrated force sensor

Wafer Positioning and Bonding for Advanced Packaging

CHALLENGE

Precision Control in 6DoF

- Bonding requires high positioning resolution and accuracy in multiple axes.
- Fast detection of contacts and transition to force controlled operation impacts process throughput.
- Process forces impact process outcome and critically the yield.

Dynamic Performance

Move-and-settle time and acceleration limit tool output; added mass and compliance stretch settling times.

Clean Operation

Guides, bearings, and lubricants generate particles requiring airflow to manage them



SOLUTION

Contact-Free Levitation Over Long Travel

Accuracy does not rely on a mechanical guide. Minimal disturbances in force signal enables detection of any spike in force.

High Force Density, Low Moving Mass

Direct actuation and low moving mass for high acceleration and short settling times.

No Contact, No Lubricants, No Wear

With contact-free bearing and actuation, no particles or airflow are generated, eliminating mechanical disturbances.



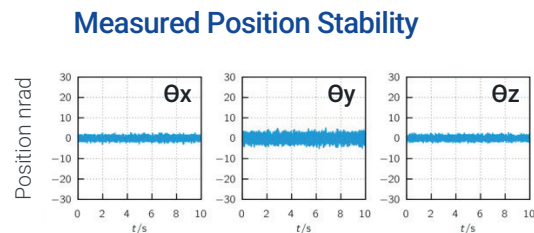
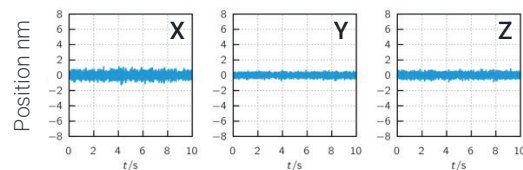
RESULT

One Stage

- Long-range travel, nanometer positioning, and force control in one contact-free body.
- Fewer interfaces, less commissioning effort.
- With all process-critical motion contained in one stage, the overall machine is simplified.

New Machine and Process Concepts

- Full control over position, force, and torque in 6DoF.
- Switchable control modes in each DoF for e.g. position control in XY and RZ, virtual stiffness in RX and RY, and constant velocity approach in Z with contact detection and force application.
- Constant monitoring of forces and torques to ensure process consistency.



Preliminary measurements performed in lab environment

	RMS	p-p
x/nm	0.33	2.50
y/nm	0.20	1.48
z/nm	0.24	1.81
θ_x /nrad	0.77	6.18
θ_y /nrad	1.43	10.53
θ_z /nrad	0.80	5.53

LET'S TALK ABOUT YOUR APPLICATION

Discuss your process requirements and the right approach with our experts.

Physik Instrumente (PI) SE & Co. KG

Auf der Römerstraße 1 | 76228 Karlsruhe, Germany

Phone +49 721 4846-0

info@pi.ws | www.physikinstrumente.com

Wafer Positioning for Inspection and Metrology

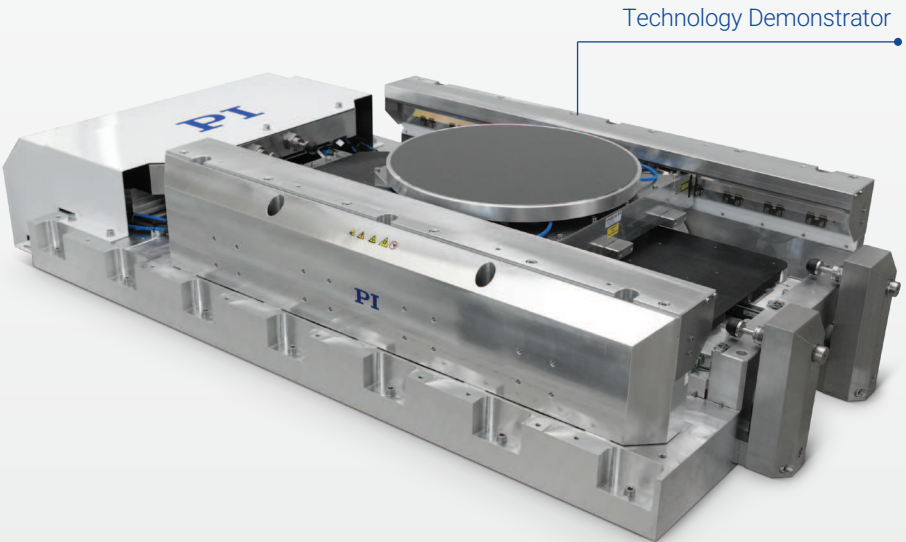


High-Precision, Highly Dynamic Positioning for High-Throughput Tasks

High-throughput inspection and metrology demand nanometer accuracy and the dynamics to measure on the fly. A magnetically levitated, long-travel wafer stage delivers both, holding focus and stability under high acceleration while active 6-axis control and contact-free operation keep every measurement clean and repeatable across the full wafer.

Key MagLev Advantages

- ✓ **Dynamic Focus Tracking** — Active height control during scanning
- ✓ **Active Error Compensation** — Correction of tip, tilt, and cross-axis errors
- ✓ **Contact-Free Operation** — No lubricants, wear, or particle generation



					
Dynamics	Auxiliary Axes	Primary Stroke	In-Position Stability	Repeatability	Dynamic Focus Tracking
Acceleration: 2* ... 6 g Velocity: 400* ... 2000 mm/s	Y: $\pm 200 \mu\text{m}^*$ Θ_{XY} : $\pm 0.5 \text{ mrad}^*$ Θ_Z : $\pm 1 \text{ mrad}^*$	Wafer positioning: 400 mm* (X)	Z: $< 2 \text{ nm}^*$ (p-p) Θ_{XYZ} : $< 20 \text{ nrad}^*$ (p-p)	Double-digit nanometer*	Z: $\pm 200^* \dots 1000+ \mu\text{m}$ Z: $> 200 \text{ Hz}^*$

* Asterisked values represent the performance of the demonstrator shown; additional values indicate achievable performance with different system configurations.

Wafer Positioning for Inspection and Metrology

CHALLENGE

Precision Control in 6 DoF

- Every path deviation causes errors in feature position and distorts images.
- Residual motion and drift during imaging can blur features and limit measurement repeatability.
- Cross-axis and out-of-plane errors tilt the sample, causing defocus and Abbe errors.

Dynamic Performance

Tool output is limited by move-and-settle time and acceleration – not just peak speed. Added mass and compliance further stretch settling times.

Clean Operation

Guides, bearings, and lubricants generate particles requiring airflow to avoid sample contamination.



SOLUTION

Contact-Free Levitation Over Long Travel

- Accuracy does not rely on a mechanical guide.
- Position stability only depends on sensors and motor current ripple and is no longer limited by air bearing noise.
- Dynamic compensation enables high acceleration with minimal tipping and tilting.

High Force Density, Low Moving Mass

Direct actuation and low moving mass delivers high acceleration, short settling, and ripple-free scanning.

No Contact, No Lubricants, No Wear

With contact-free bearing and actuation, no particles or airflow are generated, eliminating disturbances.



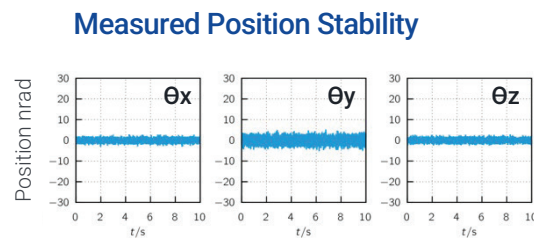
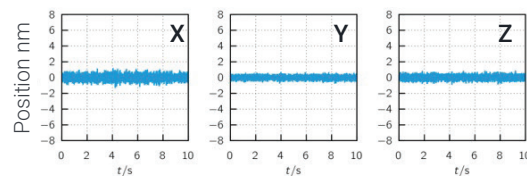
RESULT

One Stage

- Long-range travel and nanometer positioning in one contact-free body.
- Fewer interfaces, less commissioning effort.
- All process-critical motion contained in one stage simplifies the overall machine.

No Air, No Wear

- No compressed air supply, plumbing, or air film noise disturbing the measurement.
- No wear, no lubricants, no particles: stable accuracy over the whole lifetime.
- Stiffness and damping are configured in software and are thus adaptable in each process step.



Preliminary measurements performed in lab environment

	RMS	p-p
x/nm	0.33	2.50
y/nm	0.20	1.48
z/nm	0.24	1.81
θ_x /nrad	0.77	6.18
θ_y /nrad	1.43	10.53
θ_z /nrad	0.80	5.53

LET'S TALK ABOUT YOUR APPLICATION

Discuss your process requirements and the right approach with our experts.

Physik Instrumente (PI) SE & Co. KG

Auf der Römerstraße 1 | 76228 Karlsruhe, Germany

Phone +49 721 4846-0

info@pi.ws | www.physikinstrumente.com