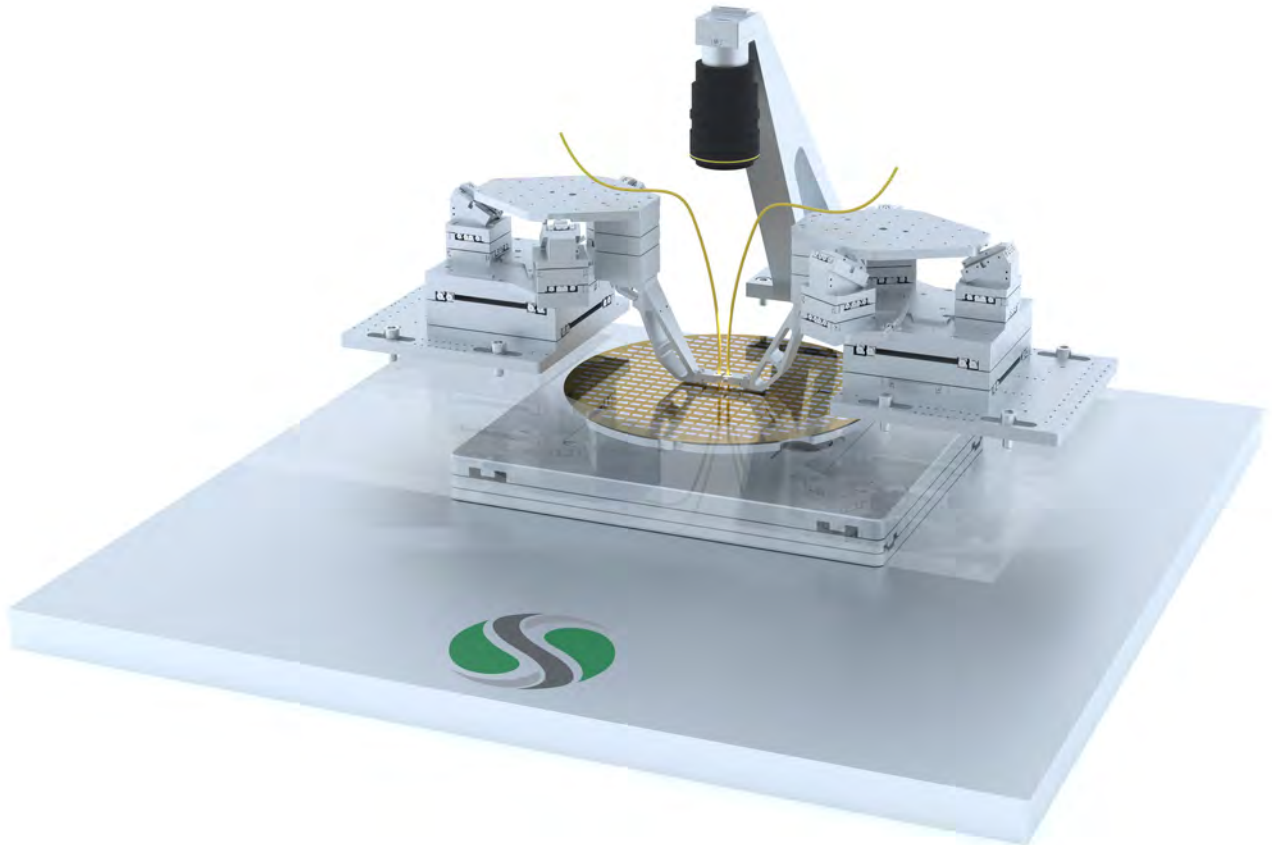


# FAST PHOTONICS ALIGNMENT

# INTRODUCTION



For fast and easy aligning of optical components as well as silicon photonics, SmarAct offers modules and subsystems that are optimized with respect to precision, size, speed and force. The combination of different SmarAct Motion technologies is key to enable fast and accurate alignment of lenses, fibers to waveguides, fibers or even Photonic Integrated Circuits (PICs) on wafers.

This document provides an overview over different modules that you can use in your alignment system. In addition to our standard modules, we are happy to offer customized modules and complete solutions. So please contact SmarAct's semiconductor and photonics specialists.

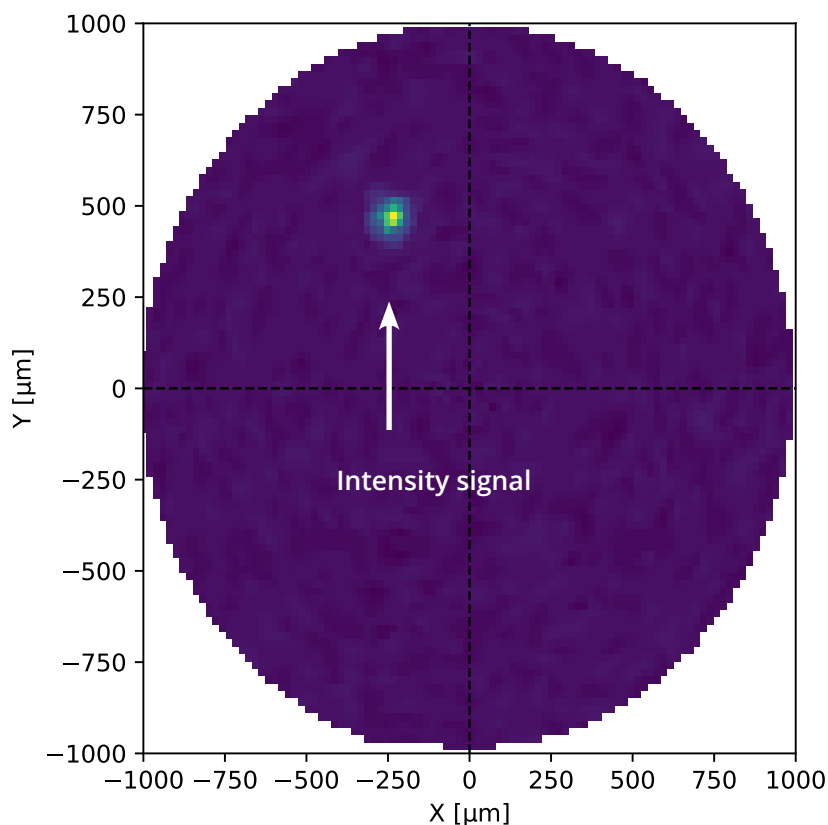
As an example, the modules can be combined to a complete optical PIC probing system. A **SMARSHIFT**<sup>®</sup> electromagnetic direct drive SOM-MS-180150M combines speed, force and nm accuracy and can move wafers or different samples. The **SMARPOD**<sup>®</sup> CLS 32.5 aligns fibers to the PICs on the wafer to couple light into and out of the wafer. The range of the **SMARPOD** is extended horizontally by 60mm x 60mm with two CLS-9292 axes. The actual fast scan and alignment is performed by an XYZ Scanner which is based on three PLF-3232, ideally combining the requirements of nm resolution and high speed. To optimize the coupling speed, the **MCS2** controller includes algorithms for trajectory movement and high-speed data capturing.

# Tailored Scan Routines in SmarAct's Framework

The choice of system hardware and the formulation of the scan routine are closely linked to the specific requirements of the application. The design of the scan routine can be programmed in various ways using SmarAct resources such as libraries and program examples tailored to Python® and LabVIEW™ for Windows and Linux. Communication can take place either via USB or Ethernet.

SmarAct's framework provides a solid foundation for developing a customized scan routine that perfectly matches the requirements of the application. This framework provides the necessary structure and flexibility to develop a scan routine that is perfectly tailored to the specific requirements and ensures optimal performance and the desired results.

## Searching for Light and Pre-Alignment



Any of the hardware motion system modules can readily be deployed to execute the "first light search routine". For the intensity signal, for example, a power meter can be connected via the I/O module of the SmarAct MCS2 controller. The tracking of the intensity and the parallel recording of the data of the coordinates in the translative direction of movement X-Y-Z allows sufficient scope for a fast

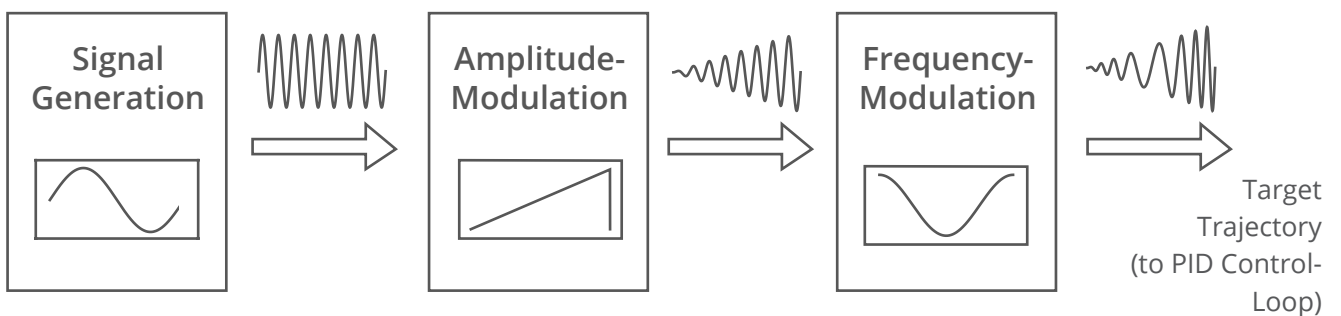
and efficient search for light. Even double-sided coupling at the same time can also be realized with the right combination. As an additional option, the height between the fiber and the surface can be kept constant with capacitive sensors on the fiber holder to ensure the reproducibility of the measurement, e.g. with divergent beam profiles. The capacitive sensor system also serves to prevent „crashes“.

# Fine-Tuning and Optimization Algorithms

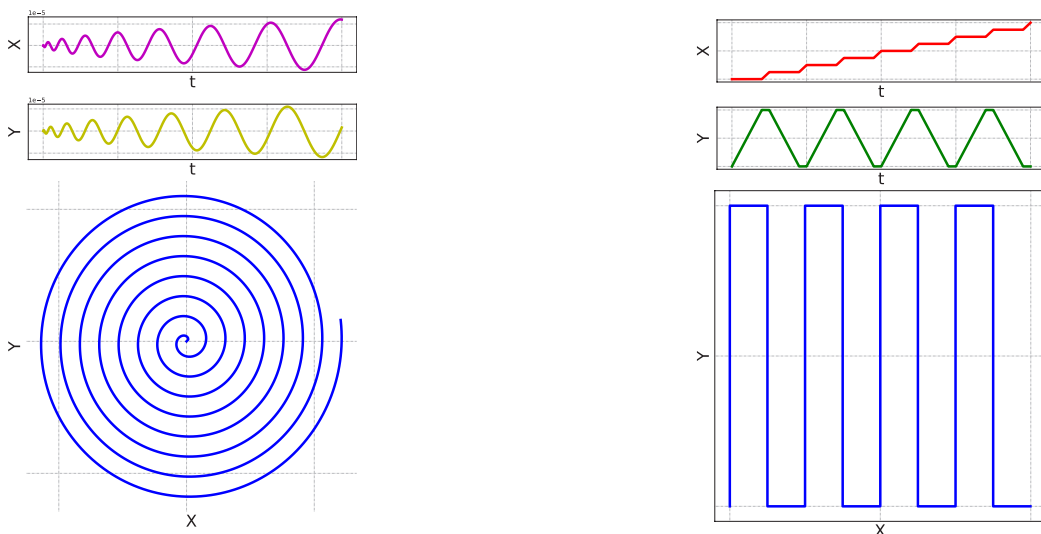
The heart of the system is the XYZ piezo scanner, whose control is seamlessly integrated into SmarAct's MCS2 controller with scan algorithms at low level.

## Optimal Scan Shapes for Maximum Efficiency

One of the main modules is the „Waveformgenerator“. This feature allows for the generation of movement trajectories with arbitrary shapes through signal generation, amplitude modulation, and frequency modulation. By utilizing frequency modulation, it becomes possible to optimize the speed between the x and y movements, ensuring a constant overall path speed.

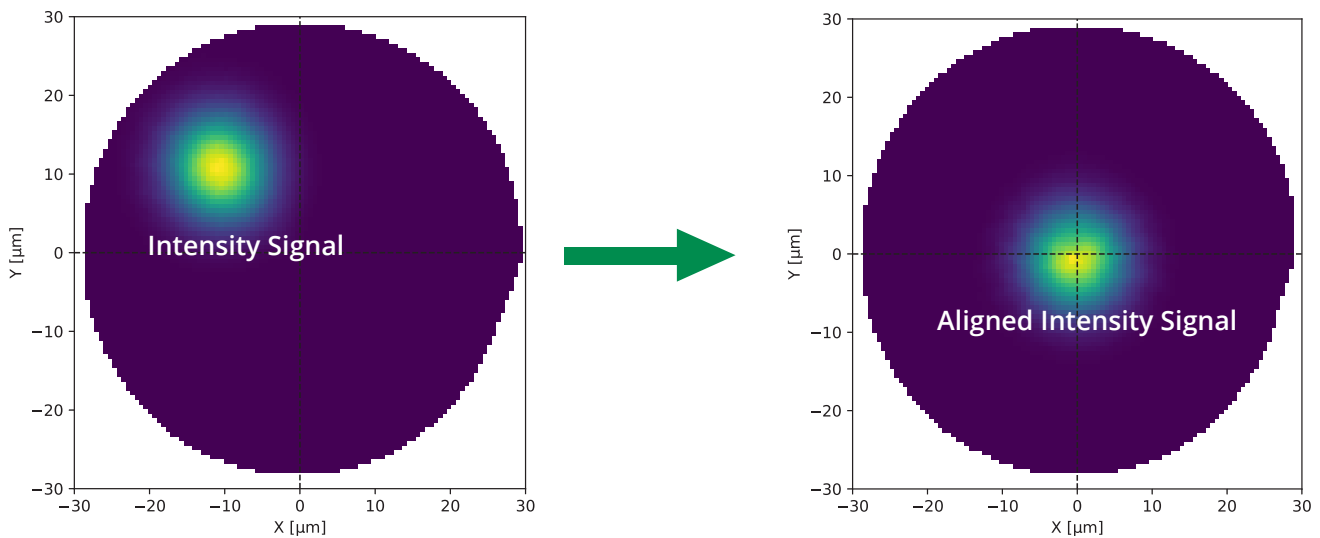


In different applications, utilizing a customized shape can significantly enhance the coupling speed. Spiral scanning, for example, is ideal for precise point scanning of a surface, while rectangular scanning is particularly effective for aligning the fiber to components close to edges. By selecting the most suitable form for the specific requirements, the efficiency and effectiveness of the scanning process is optimized.

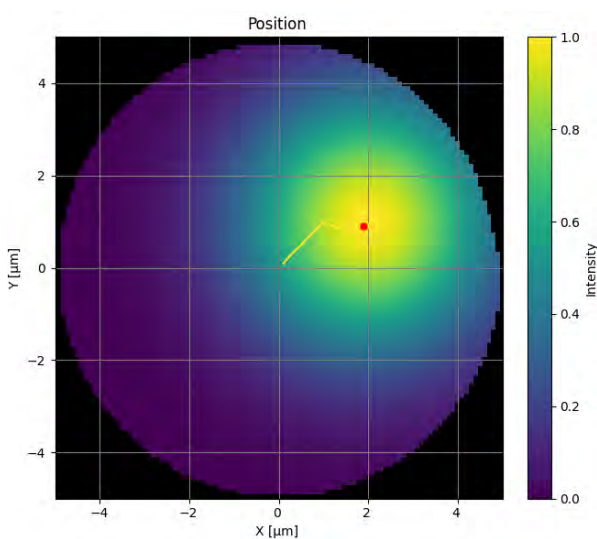


## High-Speed Signal Processing

To process external signals, such as measuring the intensity of light emitted by an optical component, an I/O module is employed. This module facilitates the measurement through a power meter. As the scan progresses, the position-dependent signals are stored using an integrated capture buffer, allowing for a maximum capture rate of 50 kHz. These stored signals can then be accessed for subsequent processing. The fine alignment module allows scanning and alignment in less than a second.



## Fine Adjustment with Gradient Search Algorithm



A “gradient search algorithm” can be used to further reduce the alignment time with a more direct approach. To find the maximum power, the algorithm analyzes the signal change with each movement and adjusts the direction of movement in the direction of the largest increase.

This step-by-step optimization not only enables fast and automated initial alignment, but also continuous optimization. Position drift can also be reliably detected and compensated for - for permanently stable and optimum signal quality.

# Modules

In the following overview you can see which SmarAct modules are available for pre-alignment, fine scanning, gripping, Wafer and sample handling.

## Pre-Alignment Modules

For the pre-alignment of fibers or optical components over a desired location on the wafer, a dedicated SMARPOD® or XYZ-system is available.



SMARPOD CLS-32.5 (6 DOF)

Translation (X, Y, Z): 20 mm, 20 mm, 10 mm

Rotation ( $\theta_x, \theta_y, \theta_z$ ): 3°, 6°, 8°

Smallest Increment: 1 nm / 1  $\mu$ °

Unidirectional Repeatability:  $\pm$  50 nm



XY CLS-9292 (2 DOF)

Travel Range (X, Y): 63 mm, 63 mm

Smallest Increment: 1 nm

Unidirectional Repeatability:  $\pm$  40 nm



XYZ CLS-5252 (3 DOF)

Travel Range (X, Y, Z): 31 mm, 31 mm, 31 mm

Smallest Increment: 1 nm

Unidirectional Repeatability:  $\pm$  40 nm

## Fine Alignment Modules

The XYZ scanning element combined with the Fast Scan & Align algorithm is the key to a fast and repeatable optimization.



XYZ-Scanner PLF-3232

Max. Scan Range: 60  $\mu$ m

Scan Resolution: < 1 nm

Repeatability:  $\pm$  3 nm in x-y Direction  
 $\pm$  10 nm in z Direction

## MCS2 Controller including Fast Scan & Align Algorithm



- Control of up to 15 channels per unit
- Connection via USB / Ethernet / EtherCAT
- FPGA-based algorithms

### Waveform generator for scanning

- Configurable Waveform: triangle, staircase, sinus, custom
- Frequency: 0.1 Hz to 1 kHz

### Gradient-Search-Algorithm

### Data Buffer for fast read-out

Max. Capture Rate: 50 kHz

Fast Scan and Align in under 1 s

MCS2 Controller

## Gripper Modules

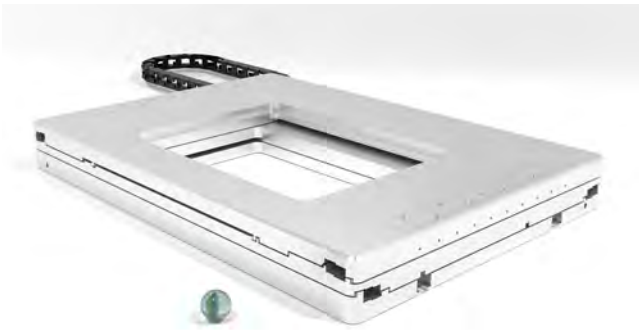
For handling small samples or optical or electrical components, SmarAct also offers micro gripper modules to change an alignment system to a powerful handling system. SmarAct grippers are versatile and can be customized to fit your application and your samples.



- Open-/closed-loop operation
- Exchangeable Gripper Jaws
- Standard and customized Gripper Jaws
- Compatible to different environments

SGE-17 Series

## Wafer and Sample Handling Modules:



SOM-MS-180150M (2 DOF)

**Travel Range (X, Y):** 121 mm, 101 mm

**Velocity:** 300 mm/s

**Unidirectional Repeatability:**  $\pm 200$  nm



MLL-400 (2 DOF)

**Travel Range (X, Y):** 300 mm, 300 mm

**Velocity:** 200 mm/s

**Unidirectional Repeatability:**  $\pm 90$  nm



EM TriPod 400 (3 to 6 DOF)

**Translation (X, Y, Z):** 300 mm, 300 mm, 16 mm

**Rotation ( $\theta_x, \theta_y, \theta_z$ ):**  $\pm 3.25^\circ, \pm 3.5^\circ, \pm \infty$

**Smallest Increment:** 20 nm

**Velocity:** 20 mm/s in X, Y

**Max Normal Force:** 80 N

**Resolution (X,Y,Z):** 10 nm, 10 nm, 3 nm

**Resolution ( $\theta_x, \theta_y, \theta_z$ ):**  $1 \mu^\circ, 1 \mu^\circ, 10 \mu^\circ$

**Unidirectional Repeatability (X,Y,Z):**  $< \pm 90$  nm,  $< \pm 90$  nm,  $< \pm 25$  nm

**Unidirectional Repeatability ( $\theta_x, \theta_y, \theta_z$ ):**  $< \pm 15 \mu^\circ, < \pm 15 \mu^\circ, < \pm 25 \mu^\circ$

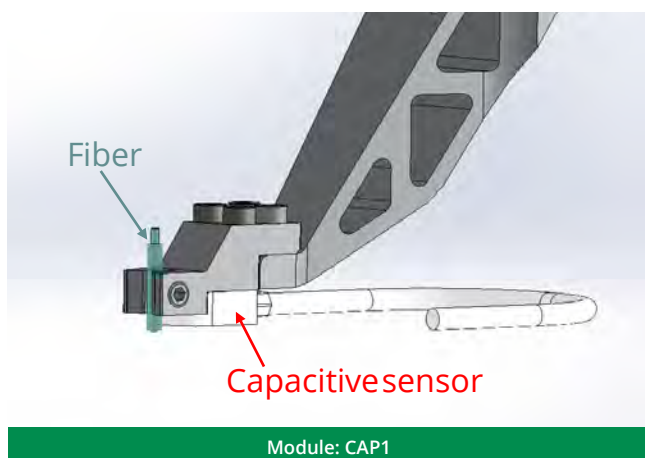
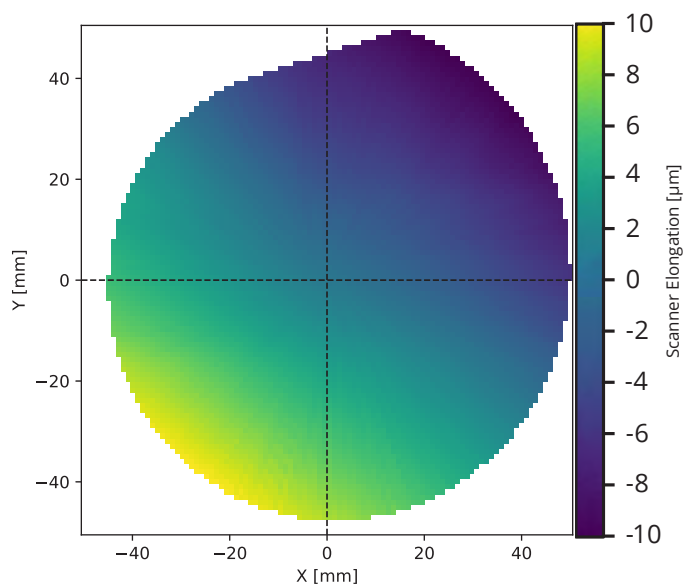
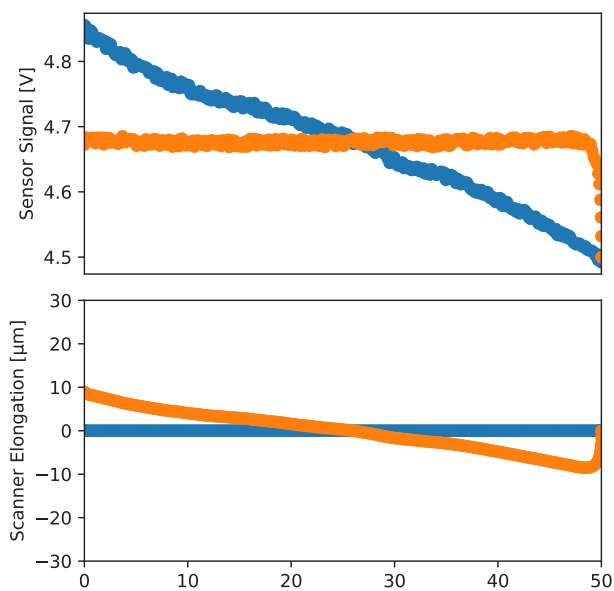
The correct selection of the sample and wafer stage is essential to achieve the highest processing efficiency within your application. With its range of electromagnetic stages SmarAct offers solutions that combine speed and accuracy at up to six degrees of freedom.

# Extensions and Tools for Fiber Holders

In certain applications, it is highly beneficial to incorporate a distance measurement and control feature. For example, distance control proves to be particularly advantageous when conducting full-wafer testing, where semiconductor wafers often exhibit a specific curvature.

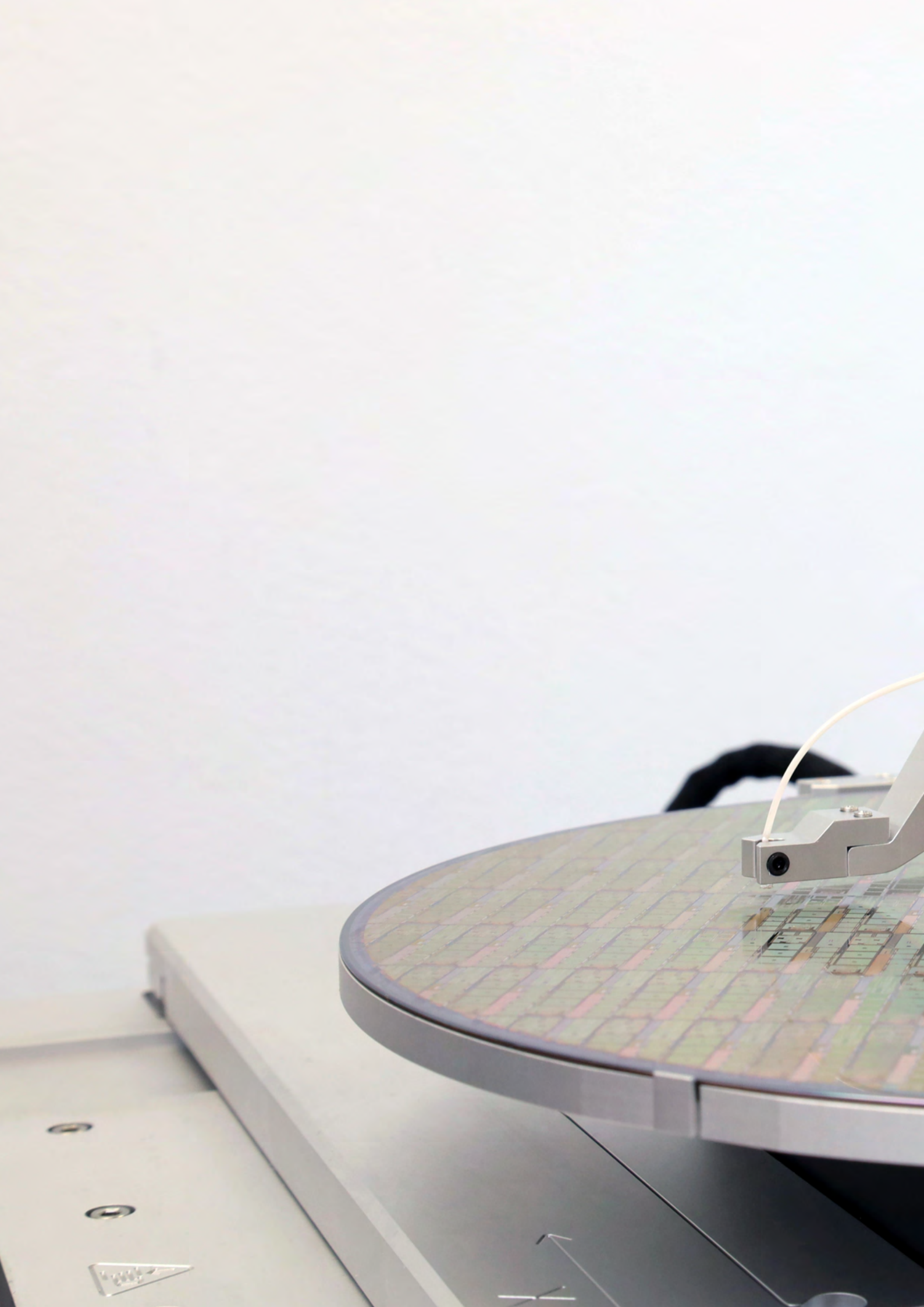
In addition to movement in the X and Y directions, a sensor detects a signal that correlates with the change in distance,  $\Delta z$ . This signal is used for

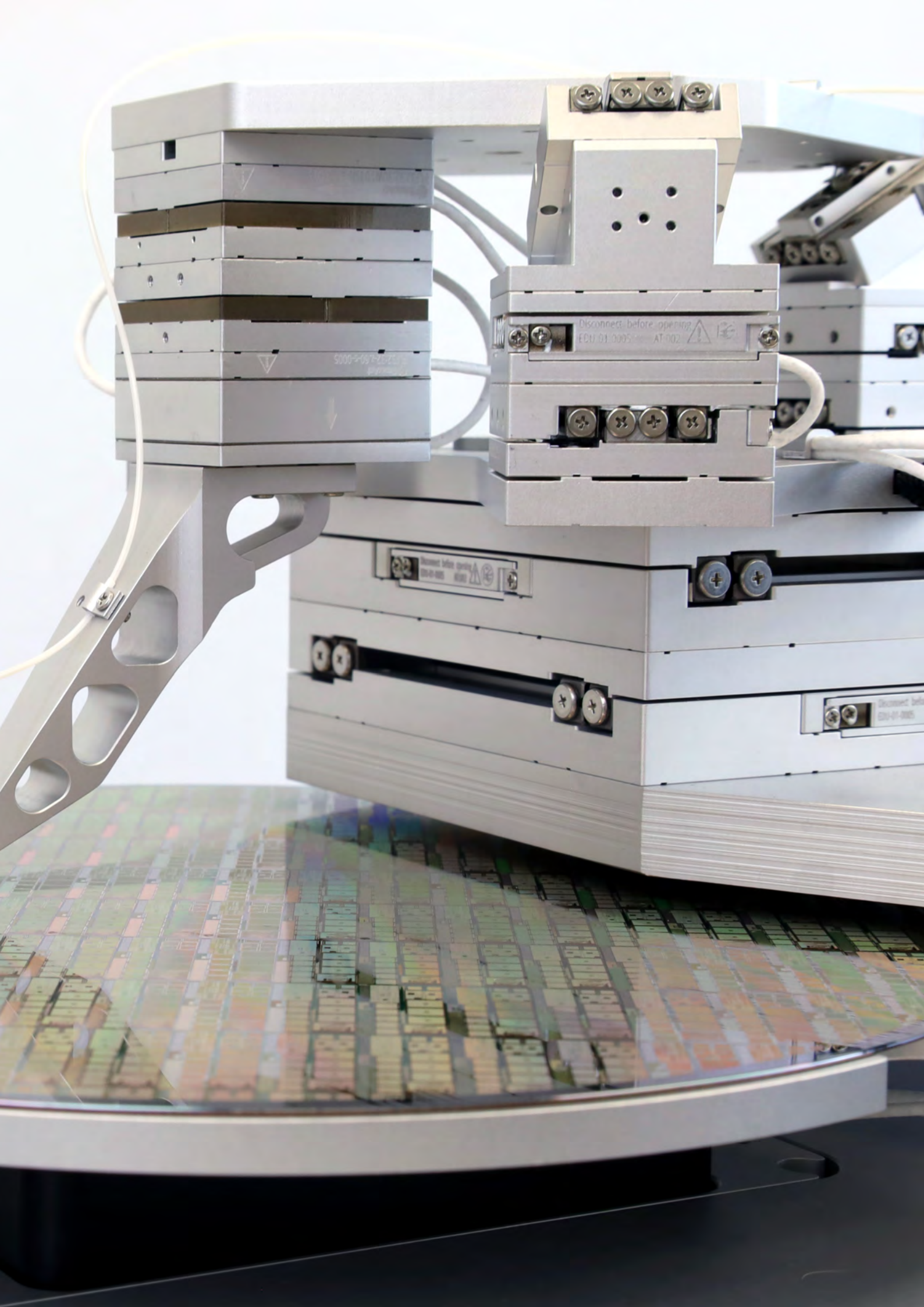
precise distance control. Both line scans (as shown in the left-hand image) and 2-dimensional scans (as shown in the right-hand image) are possible. This allows the fiber to remain equidistant across multiple measurement points, which is essential for the reproducibility of intensity measurements with divergent beam profiles. In addition, unfortunate accidents caused by collisions with the fiber are prevented.



Linearity:  $\leq \pm 0.09 \mu\text{m}$

Resolution: 10 nm





With the development and production of market-leading solutions in the field of high-precision positioning, automation and metrology, the SmarAct Group reliably accompanies their customers in achieving their goals. The broad product portfolio – from single positioning stages to complex parallel kinematics, miniaturized robots, control systems and measurement technology – is complemented by automated microassembly solutions. Even the most challenging customer requirements can be met by maximum adaptability and complete in-house production.

Since its founding in 2005, SmarAct has steadily grown from a small team of engineers to a group of companies with three independent business units and over 270 highly skilled members. Today, SmarAct relies on years of experience and, above all, on a very passionate team with unconditional customer focus.

## Headquarters

### **SmarAct GmbH**

Schuetze-Lanz-Strasse 9  
26135 Oldenburg  
Germany  
T: +49 441 – 800 87 90  
T: +49 441 – 559 79 18 0  
Email: [info-de@smaract.com](mailto:info-de@smaract.com)  
[www.smaract.com](http://www.smaract.com)

## USA

### **SmarAct Inc.**

2140 Shattuck Ave. Suite 302  
Berkeley, CA 94704  
United States of America  
T: +1 415 – 766 90 06  
Email: [info-us@smaract.com](mailto:info-us@smaract.com)  
[www.smaract.com](http://www.smaract.com)