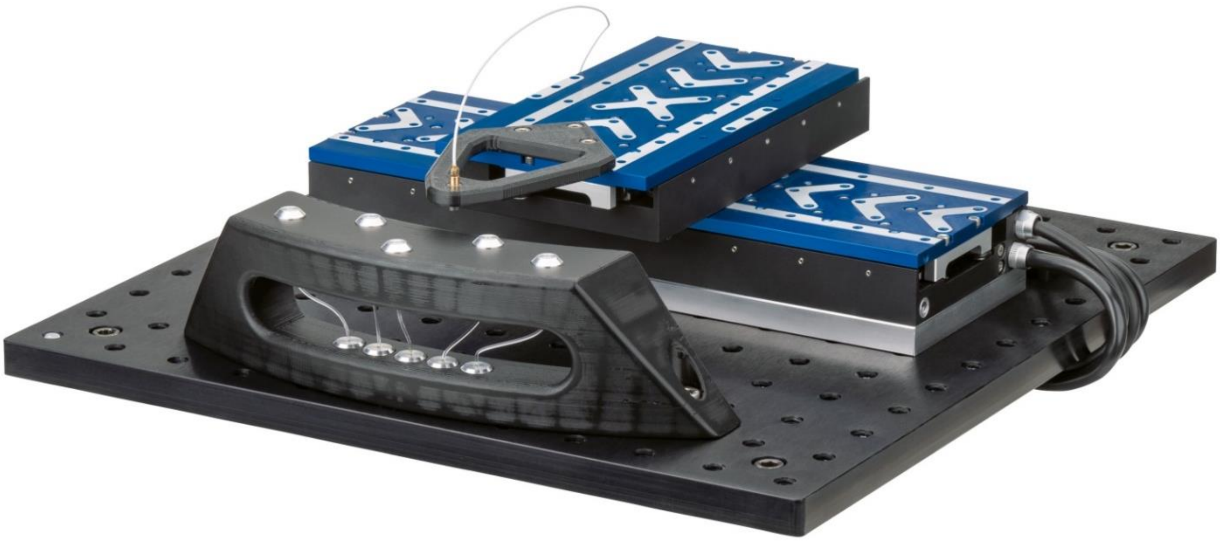
-- Scott Jordan --

Enabling Large-Format Industrial Productivity

Award-Winning PI Fast Alignment Technology Comes to ACS Controls



1 Introduction

PI's award-winning fast optimization technology has proven to dramatically improve production economics in processes as diverse as photonics wafer probing, device packaging, and chip testing and even laser and optical equipment manufacturing. The combination of blazing speed, nanoscale performance and industrial robustness is reducing costs and improving yield worldwide.

Now the flexible combination of PI´s industrial stages and new alignment-enabled controls from ACS address additional tough throughput and yield challenges for photonics production. Large-format production processes can now be addressed, with each mechanism contributing intelligent alignment for test and assembly. This opens new possibilities for hyper-efficient systems architectures.

PI's unique optimization functionality is firmware-based, offers the unique option of parallel alignment across multiple inputs, outputs and degrees-of-freedom, and can improve process throughput by a factor of 100 or more compared to legacy approaches.

2 Background

Alignment automation emerged three decades ago. In an era dominated by single-mode pigtailing applications, it was an enabler that helped eliminate costly manual submicron-alignment processes during device test and assembly.

The photonics world has advanced, though. Wafer-based photonics now drives the industry. Adoption volumes are orders of magnitude higher than in the 1997-2001 photonics boom, and the devices are quite different: for example, multiple I/Os necessitating multiple degree-of-freedom optimization, with each coupling frequently presenting non-Gaussian multimode cross-sections and interactions across channels, inputs and outputs, and DoFs. While these challenges can often be met with legacy alignment techniques, the minutes-scale times required present serious challenges for production economics.

PI's unique, fifth-generation optimization technology, now well-proven in the field after its 2016 introduction, allows simultaneous alignment across channels, I/Os and DoFs, even when they interact due to optical or geometric crosstalk. The dazzling throughput improvement of this parallelism can often exceed a factor of 100, as PI routinely demonstrates in live demonstrations at conferences. So, for example, an array-device alignment that previously took a few minutes can often now be achieved in a second or less.

PI's first implementations of this technology were in fast piezo stages and hexapods. Now its key functionality has been extended to ACS controls, bringing the benefits of ground-breaking productivity to large-format applications as diverse as photonics wafer probing, device packaging, and chip testing and even laser and optical equipment manufacturing.

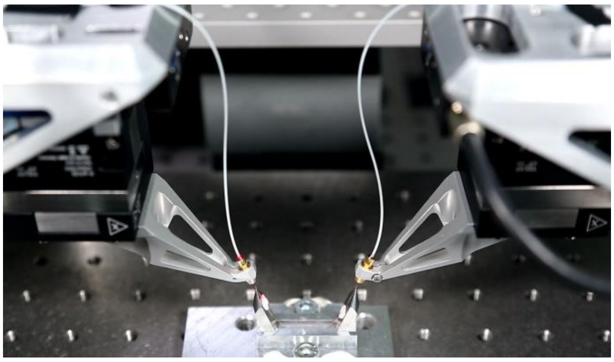


Abb. 1 The double sided fibre alignment systems from PI enables simultaneous positioning of input and output fibers for chip testing and wafer probing

Moreover, the algorithms offer seamless compatibility with today's photonic devices, which often prove challenging for legacy approaches. For example, there is no implicit assumption of circular symmetry embedded in the algorithms. That posed no issues in 1997 but can be highly sub-optimal for latter-day photonic devices. It can practically be stated that these systems can virtually "optimize anything," which is definitely not the case for the decades-old approaches still commonly offered.

3 A deeper dive

Two alignment techniques are most useful today: *area scans*, and *gradient searches* for fast optimization and tracking.

3.1 Area scans

A good example of a legacy approach to an area scan is a classical raster or serpentine scan, which sweeps one axis, then increments its orthogonal axis, and repeats until the area is covered. Variations on this theme are common, including stepwise hill-climbs. But these approaches pose fundamental issues today. The stopping-and-starting adds settling time and causes vibration throughout the system, and the linear acquisitions can lead the system to actually de-align in common situations of asymmetric coupling profiles.

By comparison, PI's firmware-based area scans use smooth, continuous sinusoidal and spiral patterns of selectable frequency. So system resonances can easily be avoided, allowing the non-stop scan to proceed without vibration. The result is considerably higher speed. Add built-in modelling in some controllers, and the system can determine the peak (or even the centroid of a top-hat coupling) with good accuracy and speeds down to a few hundred milliseconds.

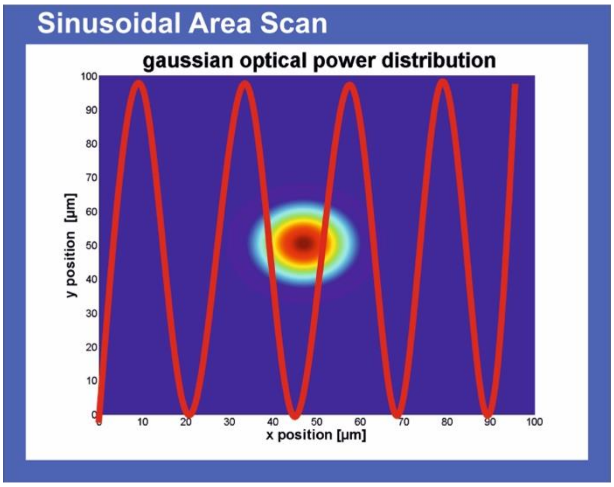


Abb. 2 In the case of the sinusoidal scan routine the defined surface is scanned continuously without vibration-inducing acceleration or deceleration phases. Surface, starting point, line distance, and success criteria can be defined by the user.

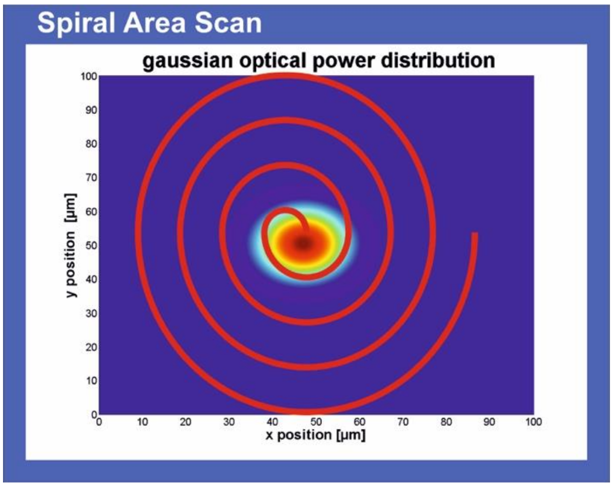


Abb. 3 In the case of the spiral scan routine, a defined area is scanned helically, whereby either a constant angle or a constant path velocity is maintained. Its selectable operating frequency helps to avoid system resonances.

3.2 Gradient search

The digital gradient search was first developed in 1987 and, until now, has been mostly unchanged in its implementation through four subtle generations of the technology. A small, circular motion causes the coupling signal (or other figure-of-merit) to vary, and this variation can be analysed in phase and amplitude to determine the instantaneous gradient. This allows a fast and direct path to optimum, with tracking possible for appropriate mechanisms.

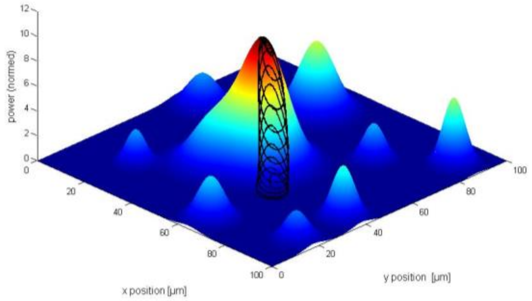


Abb. 4 Ground-breaking results can be achieved with the unique implementation of the gradient search algorithm. If the light signal is present, this gradient search makes it possible to find the signal maximum in typically less than 1 second.

PI's radical fifth-generation approach builds on this classical foundation to enable multiple gradient searches to proceed in parallel. For example, this allows an XY lock-on to be performed at the same time a theta-Z optimization runs— an essential combination for any array-device alignment. This fast, parallel execution replaces the time-consuming iterative loop of separate XY and theta-Z alignments that was formerly required. One step instead of dozens!

3.3 PI´s latest breakthrough

Since 2016, firmware-based fast area scan, gradient search and parallel gradient-search technologies have been implemented in PI's powerful piezo nanopositioner and hexapod controllers. Now fast alignment functionality is available for ACS controls. Combined with PI's large industrial stages (including spindle-driven and linear-motor stages, gantries and air-bearing assemblies), this forms a foundation for especially high-throughput applications involving large-area processing, such as when devices are processed in trays, or across several stations, or on an indexing platform or conveyor.

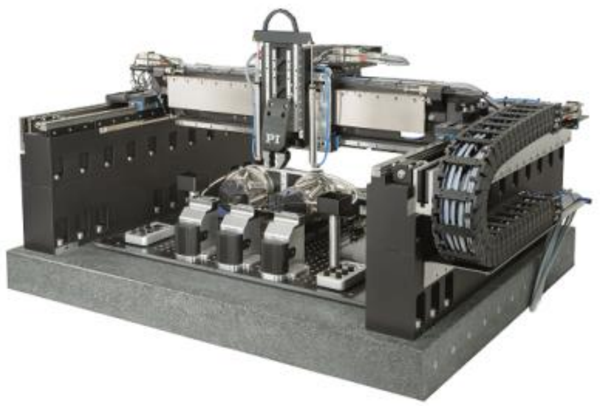


Abb. 5 Example automation subsystem for multi-channel automated photonic-device assembly tools, based on the proven double-sided F-712 HA2 alignment system and PI´s multi-axis gantry system, offers an idea for further workflow automation.

ACS controls lead the industry in modularity and performance. Based on an EtherCAT open, distributed architecture, they support absolute encoders, minimizing system start up times, easing initialization approaches and reducing collision risks. ACS' yaw control (combined with PI's highly optimized joint construction) provides industry-leading orthogonality correction and minimizes risk of axis binding—a distressingly common issue for older architectures. True MIMO gantry control plus dynamic cross axis control yields uniform performance over the gantry area, eliminating grid-based approximation methods and their consequent lowest-common-denominator approach to tuning over large areas. Together, these mean higher performance and reproducibility in your application.

These benefits come with PI's and ACS' rich offering of global support options, ranging from on-site Quick Start and training, to extended warranties and service plans, to consulting and co-engineering, to application and software consultation and quick-port approaches for key customers transiting from other architectures.

Abb. 6 This conceptual demo shows how PI's fast alignment can apply to large-area applications such as pick-and-place, and the screening, assembling, and testing of photonic devices. From the wafer, through coupon and chip, to the packaged product.

3.4 Summary

Photonics today is serious business, with a rapid rate of innovation and churn and broad adoption by important semiconductor and networking players. Manufacturing and testing these devices demand flexibility and high performance from production systems and tooling. Multiple studies have spotlighted alignment time as the highest cost contributor to photonic device fabrication, both from the lengthy process times formerly required and from the repeating requirement for alignment throughout the production process. PI's revolutionary fast alignment technology is unmatched for meeting these challenges, and now it is deployed in large-area mechanisms based on a modular, open-architecture approach ideal for systems integration and tooling platforms.

4 Author

Scott Jordan is head of the photonics market segment in the globally active PI Group, and a PI Fellow. He lives in Silicon Valley and has been with PI for over 20 years; he was active as director of NanoAutomation technologies and made a decisive contribution to continued technological development of the company. A physicist with an MBA in Finance/New Ventures, Scott is well known in the community for his passion and engagement.

5 About PI

Well known for the high quality of its products, PI (Physik Instrumente) has been one of the leading players in the global market for precision positioning technology for many years. PI has been developing and manufacturing standard and OEM products with piezo or motor drives for 40 years. All key technologies are developed in-house. This allows the company to control every step of the process, from design to shipment: The precision mechanics and electronics as well as position sensors.

By acquiring the majority shares in ACS Motion Control, a worldwide leading developer and manufacturer of modular motion controllers for multi-axis and high-precision drive systems, PI has made a major step forward in providing complete systems for industrial applications with the highest demand on precision and dynamics. In addition to four locations in Germany, the PI Group is represented internationally by fifteen sales and service subsidiaries.