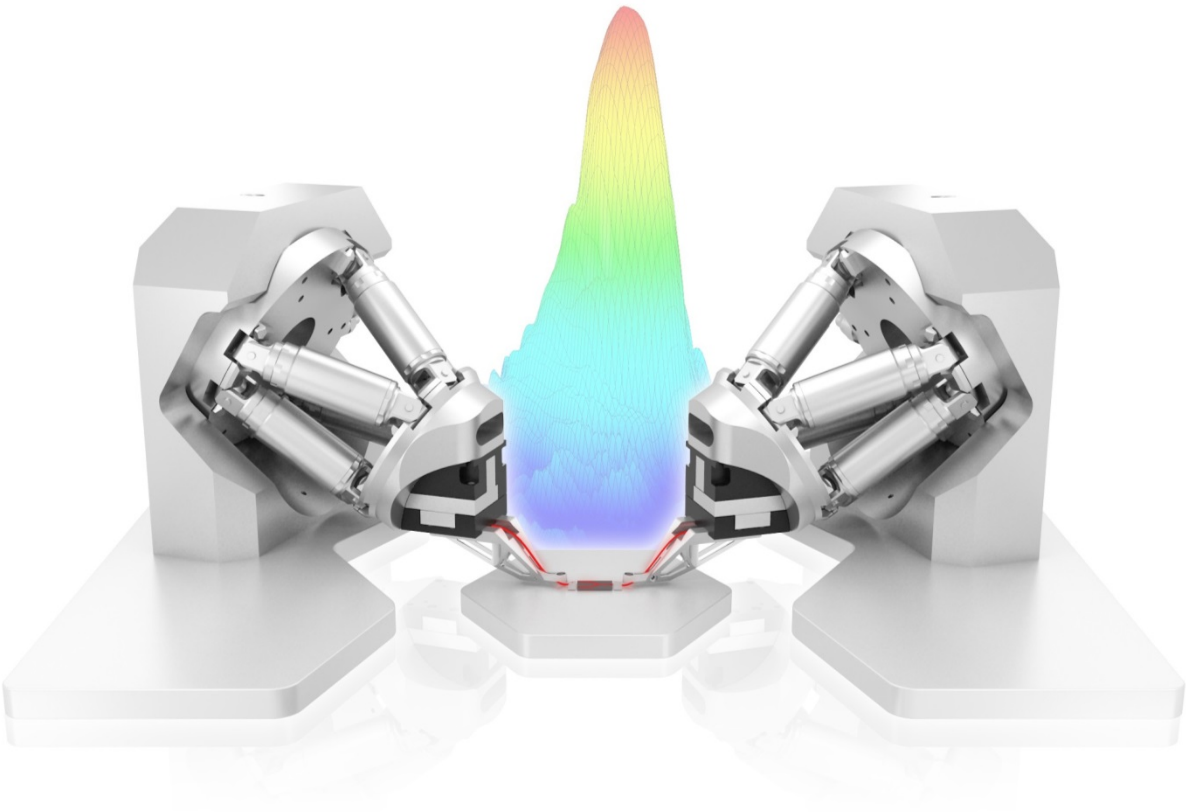
Automatic Testing of Photonics Components

Fast, Accurate, and Suitable for Industry



Silicon photonics sets the pace on the fiber optic data highway. Cloud computing, server farms, big data, fast Internet access as well as a large number of other computer-supported services that demand high transmission speeds, benefit from data rates in the TBit/s range.

However, a number of challenges must be overcome for production and testing of the latest generation of silicon photonics wafers. Automated solutions must function reliably under industrial conditions and work around-the-clock with great accuracy. At the same time, individual solutions are required because the wafer can make very different demands on the testing and production equipment.

Silicon photonics (SiP) uses standard, easily scalable processes optimized for mass production of semiconductor components. With SiP, electronic logic circuits (such as those used for computing) and optical transceivers are integrated into the same wafer. The resulting low-power microchips are then able to transmit data at bandwidths in the Tbit/s range and with low heat generation.

However, because the value of a packaged SiP circuit goes up significantly compared to the raw circuit on a wafer, it is critical to introduce wafer-level testing of each circuit before dicing and packaging. Optical inputs and outputs must be tested. The precision required to do this is several orders of magnitude higher than is possible with traditional electrical wafer probing equipment.

Inputs and outputs need to be aligned precisely to the optical fibers connected to the test equipment. That is definitely not a trivial matter, because optical waveguides in silicon wafers normally have a core diameter of only 150 to 200 nm, and to avoid losses, alignment equipment must have at least 10-times higher resolution.

Managing this type of automation task is therefore a considerable challenge: Maximum precision during handling, positioning and adjusting is just as necessary as the highest possible speed for meeting the demands made by industrial production.

Precision Fiber Alignment: Multi-Channel Fiber Adjustment in Real Time

As solution supplier for drive technology and precision positioning systems, PI (Physik Instrumente) has taken a close look at this and developed a new complete system for fast fiber alignment, which can align, test, and optimize the light input and output at each input and output coupling point in less than one second (Fig. 1).

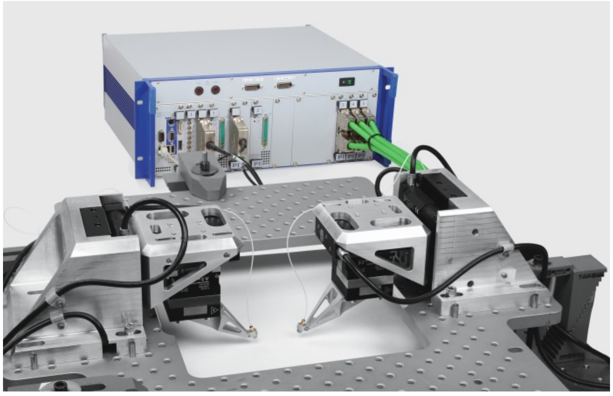


Fig. 1 Industry-suited complete systems for wafer probing in silicon photonics

This guarantees fast data throughput rates during industrial production. The system consists of two compact identical positioning units which, with a small footprint of 100 × 100 mm require very little installation space. The heart of the system is the application-specific controller with a variety of built-in alignment and tracking algorithms required for optical alignment and therefore lightens the burden on the higher level control.

The host computer communicates with the controller via Ethernet, USB 2.0 or an RS-232 interface. The system comes with a high-performance software package that allows the user to quickly develop applications under Windows, Linux, and OS/X.

Coarse and Fine Adjustment

Positioning is done in two phases: A three-axis positioning stage driven by closed-loop DC motors takes care of the initial task of coarse adjustment; it travels to the respective coupling point over travel ranges of several tens of millimeters with an accuracy of up to 50 nm.

An additional three-axis positioning unit is then responsible for fine positioning of the fibers. The system is driven by piezo actuators and achieves resolutions of 1 nm with response times in the microsecond range and travel ranges of 100 × 100 × 100 µm.

The high-performance piezo actuators are integrated into guiding systems with FEA-optimized flexure joints and are free of both friction and backlash. Because actuators, guides, and sensor work without wear, the systems are extremely reliable and durable, and are therefore perfectly suitable for industrial requirements in multiple-shift operation (24 hours and seven days a week).

More Degrees of Freedom

During wafer probing or packaging, the one or other challenge can arise depending on the application: If for example, the fibers need to be positioned at different angles or if tilting angular errors need to be compensated, more axes are required. Serial stacking of additional axes on the positioning stage is basically possible, but the limitations outweigh the advantages of this approach.

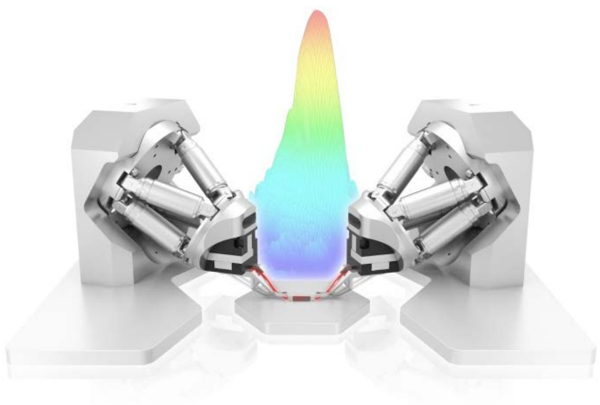


Fig. 2 Wafer level alignment with a two-side 6-axis Hexapod and a piezo scanning stage for fine alignment

The accuracy would suffer because additional guiding errors would reduce the overall precision. Instead, a more elegant and performant solution is to combine the above-described fine positioner with a hexapod parallel-kinematic positioning system. Because, in contrast to serial kinematics, all actuators in parallel-kinematic systems act directly on the same platform and therefore, it is not possible for guiding errors to accumulate as is the case with "stacked" systems and this increases the accuracy considerably.

Hexapods, which have six-axis parallel kinematics, also have further advantages for fiber alignment. Due to their low moving mass, they provide much higher dynamics (Fig. 2). The arbitrary center of rotation or pivot point is another feature, which can be programmed by a single command.

Fig. 3 This parallel-kinematic six-axis positioning system is also ideal for fiber alignment

The compact H-811 Hexapod (Fig. 3) for example, offers travel linear ranges up to 34 mm and rotational travel up to 42°. The piezo-based fine positioner integrates with the hexapod platform. For different travel ranges or load requirements, other parallel-kinematic positioning systems are available, which can be combined with the fine positioner.

The minimum incremental motion of 0.1 µm / 2 µrad, and velocities of 10 µm/s to 10 mm/s. This planar parallel positioning system is based on three XY stages driving one platform through three fixed struts. This design allows more flexibility and longer travel ranges on the XY plane.

High-Performance Software

Irrespective of which positioning system is worthy of consideration for the application, all algorithms necessary for fiber optic alignment are already integrated in the digital controller.

In addition, the digital motion controllers from PI are supplied with an extensive software package (Fig. 4), which covers all application aspects, from easy start-up, to the convenient control of the system via the graphical interface, and fast and transparent integration into external programs. A virtual controller allows development of application programs without the need to have all of the components at hand. Simulation tools, for example, help to calculate the workspace, or objects can be integrated to avoid collisions.

A mobile app enables wireless monitoring and control. Development libraries and example applications simplify implementation and a number of common programming languages and software environments are supported (C, C++, Python, Visual C++, Visual Basic and Delphi or LabVIEW, MATLAB, µManager, EPICS, TANGO as well as all programming environments that support loading of DLLs).

This allows realization of "tailored" industrial applications related to wafer probing and packaging in silicon photonics.

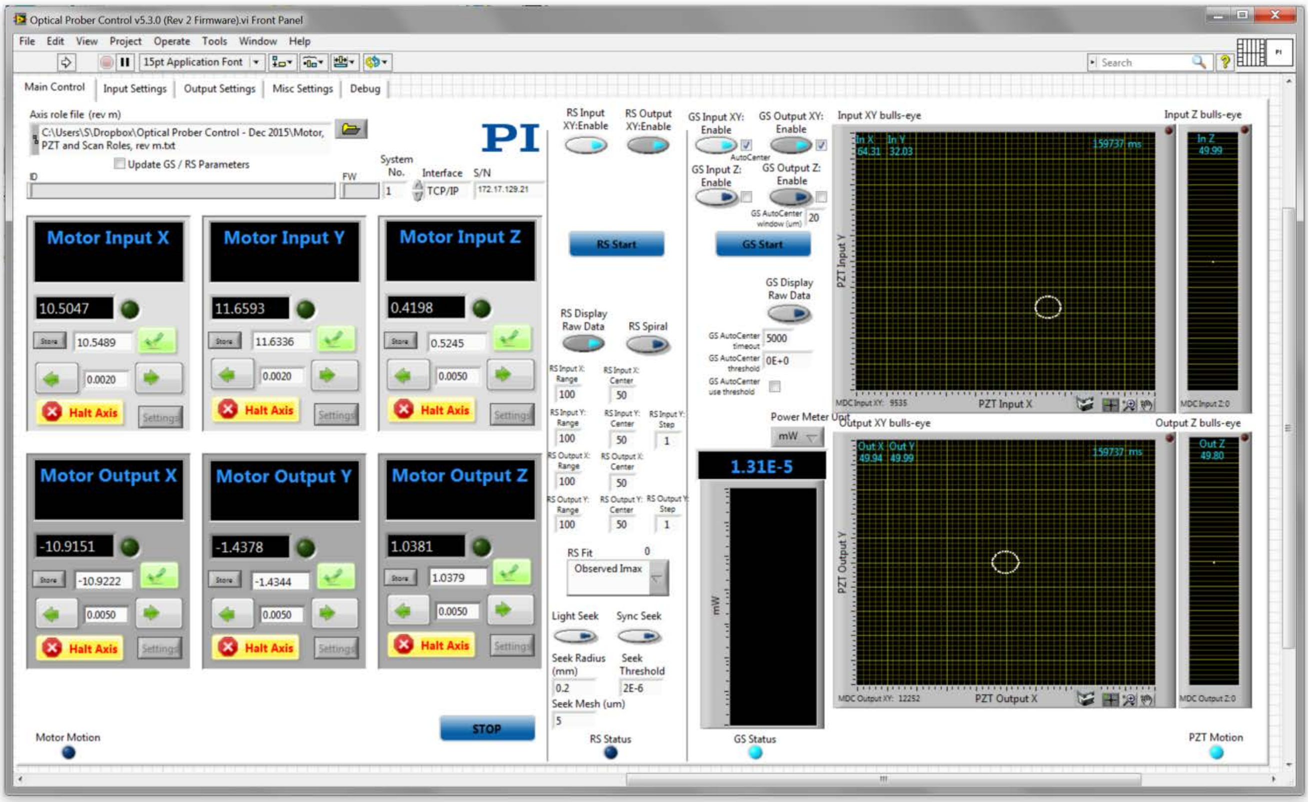


Fig. 4 An example of real-time system control

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About PI

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and fifteen sales and service offices abroad, the privately managed company operates globally. Over 850 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

The required piezoceramic elements are manufactured by its subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications as well as parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.