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Breaking Open the Silicon Photonics Production Bottleneck

Active optical alignment helps silicon photonics manufacturers speed production.

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Today's data-driven world requires fast, scalable and sustainable connectivity. Silicon photonics provides a platform for delivering this. Just as ICs integrate complex electronics with nanoscale features onto a chip, so silicon photonics enables chip-scale photonic integrated circuits (PICs). PICs incorporate essential building blocks like filters, multiplexers/demultiplexers, detectors and modulators. Fabrication is compatible with standard CMOS processing, so a PIC can combine optics and electronics. And because it leverages batch processing, silicon photonics provides great economies of scale.

The technology was initially deployed for fast, energy-efficient data center interconnects. Now it has morphed into silicon-photonics-as-a-platform, enabling applications from wearable devices to IoT sensors to autonomous vehicle LIDAR to quantum computers. And the process comes full circle, as these devices generate further bandwidth demand.

The ability to create complicated photonic circuits in a few square millimeters of silicon is a game-changer and enables all of these new applications. But it also presents major challenges. In this Q&A, Scott Jordan, head of the photonics market segment in the PI Group, highlights the core issue facing the silicon photonics industry and the strategies they need to apply to meet the demands of the moment. He is a 25 year veteran of the company, having previously served as director of NanoAutomation Technologies. He is also a PI fellow.

Q1: What's the biggest challenge today for the silicon photonics industry?

Silicon photonics is maturing into a platform enabling many fields. If you look at some of the big manufacturers of pluggable optics for data center interconnects, they might produce a few million units a year. But if we consider the projections for some of these new applications, we're talking about hundreds of millions of units per year each. The industry needs to step up its production game by three orders of magnitude in the very near future.

Q2: How can the industry adapt?

The photonics industry is where the semiconductor industry was in the mid-1980s. Back then, semiconductor fabrication involved lots of manual processes and custom machines – okay for 1980s volumes but not for what's shipping globally today. The industry grew by developing a huge ecosystem with an emphasis on standardized tools and formats, on automation, on scalability, on eliminating the human component. With massive demand looming, the photonics industry needs to learn some lessons from semiconductor manufacturing.

Q3: What are the biggest bottlenecks in the process?

Devices today differ significantly from their ancestors of two decades ago like pigtailed laser diodes. They have many inputs and outputs, presented as arrays. The challenge with array devices is that they require alignment to nanoscale accuracies, not only in the transverse plane (that is, perpendicular to the Z axis-- the optical axis), but also angularly in roll (θ_z) and often pitch (θ_x), and yaw (θ_y). Now, legacy alignment technology could only deal with each degree of freedom serially. You'd start with a transverse alignment, then make a small step toward rotational alignment. That would unfortunately impact the transverse alignment, so now we had to stop and repeat the transverse alignment, then go back to rotational alignment, and so on. A long loop!

It could take a couple of minutes. Plus, alignment has to be performed multiple times for each device, from wafer to final package, and there can be thousands of devices on a single wafer. Studies have shown that this one repeated process can account for 80% of product cost.

Q4: How do we address this problem?

Older alignment technologies can only attack one part of the overall alignment challenge at a time. So, to support the emerging silicon photonics ecosystem, PI developed a very different active optical alignment technology called Fast Multichannel Photonic Alignment (FMPA). FMPA can perform multiple alignment optimizations across inputs, outputs, channels and degrees-of-freedom in parallel. It's implemented in controller firmware and can reduce typical alignment jobs from minutes to a second or less, about a hundredfold improvement. It includes a suite of fast functionalities: area scans for finding first light and profiling, and a unique parallel gradient search for optimization and tracking. The area scans include curve-fitting options for accurate peak localization from even low-density/super-fast scans, and automatic centroid determination for top-hat couplings.

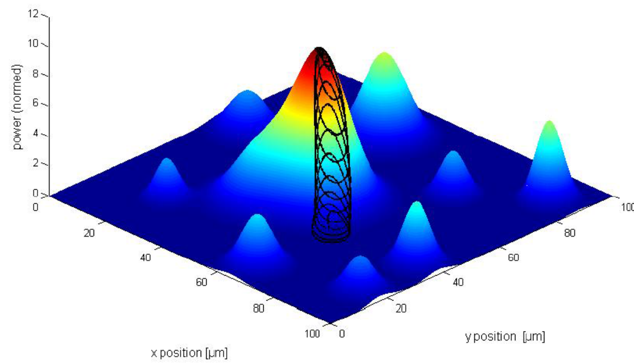

Figure 1: Plot of optical power as a function of photonic device position shows the point at which peak optical coupling is optimized (center). The black trace describes a gradient search, an advanced algorithm implemented in unique parallel form in FMPA to minimize the time required for optimizing alignment across multiple array channels and DOFs in as few as one simultaneous step.

The core concept is that alignment steps that were previously performed serially can be grouped and performed simultaneously. We can break the alignment into the sub processes mentioned earlier (transverse alignment, rotational alignment…). The user defines each sub process: Which mechanical axes are involved, which optical-signal input should the controller pay attention to, and so on. Next, the user commands the processes they want to run. The system handles their parallel execution automatically, unraveling the optical and geometric dependencies without headaches.

Q5: How do you govern the alignment process?

Usually, the job starts with an area scan to find first light and localize the peak (see figure). This generates useful spatial profiling information, too, which can be captured in the controller's internal data recorder. Then the user initiates their parallel optimizations. The entire job, from start to finish, takes perhaps one second or less. Process status can be monitored in real time, and safety features like soft limits and aborts are always available.

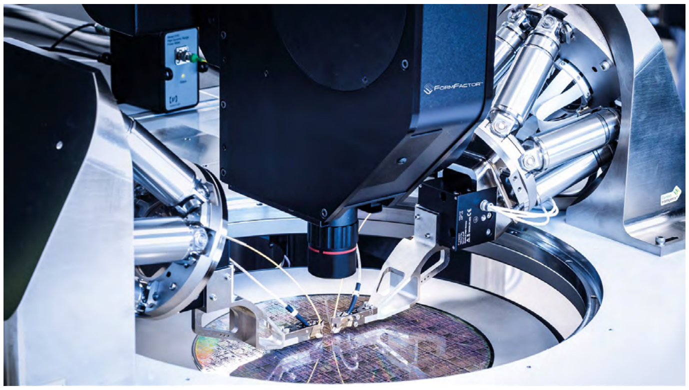

Figure 2: FormFactor's silicon photonics wafer prober fully integrates PI's Fast Multichannel Photonics Alignment engine (FMPA). The F-712.HA2 double-sided fiber alignment system actively aligns signal-carrying optical fibers to photonic structures on silicon photonic wafers to allow high-throughput, nano-precision optical probing without needing further customer development or engineering resources. (Courtesy of Formfactor)

Q6: Any parting thoughts for the industry?

To meet coming demand, the industry needs to focus on automation, scalability, and building an ecosystem. At PI, we are doing our part to solve break open the bottlenecks and team with other innovators to bring turnkey photonics alignment solutions to industry and enable productive custom developments.