



AIM Photonics

Tomorrow's Technology
at the Speed of Light

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Over the last 40 years, semiconductor-based electronics have changed the way we work, interact with one another and relax. The shrinking size of transistors—the fundamental building blocks used, e.g., as switches in computers and many other electronic devices—has led to an ever-increasing complexity in the tasks such semiconductor circuits can accomplish. Despite the field's escalating complexity, the associated costs have rapidly decreased over this same time through innovations and scaling in the underlying manufacturing technologies.

The semiconductor industry has enjoyed decades of constantly increasing integration and miniaturization, often referred to as “Moore’s Law”—continuation of which requires unrelenting cost reduction. In the process, business models have been developed that substantially contribute to productivity. These include the formation of “fabless” (outsourced fabrication) companies, dedicated foundries, independent electronic design automation companies

Liehr is the chief executive officer of the American Institute for Manufacturing (AIM) Integrated Photonics, where he focuses on creating new AIM business opportunities and is responsible for the effective and efficient operation of AIM's programs, including the State University of New York (SUNY) Polytechnic Institute's strategic 300-millimeter (mm) integrated photonic semiconductor and 3D packaging. He also is SUNY Polytechnic Institute's vice president for research. Earlier, he led the Global 450mm Consortium through the start-up phase as the general manager and was an IBM Distinguished Engineer.



The clean room used to manufacture the integrated photonic circuits that the American Institute for Manufacturing (AIM) will be providing future access to through multiproject silicon wafer production runs.

Photos courtesy of the State University of New York Polytechnic Institute.

(companies that offer design libraries and prequalified blocks of intellectual property to circuit/system designers), and equipment and material suppliers. As a result, today's microelectronics landscape is comprised of a large, disaggregated but mutually interdependent fabric of enterprises. Moore's Law enabled the emergence of the Internet, the personal computer and the laptop, as well as the cell phone and myriad other ubiquitous products that have transformed our world.

We are expecting the technological limit of scaling to be reached in the near future where any further increase in speed and complexity will increase cost, power consumption and heat too much to allow further, practical miniaturization. Light propagates through optical fibers with much less loss than what is experienced by electrical current passing through wires—a well-known fact exploited by telecommunication companies using optical fiber for more than a quarter-century. The question naturally arose of whether a photonics approach could alleviate any of these issues. To explore this question, scientists and engineers have worked for more than a decade on merging the elements of optical systems with the tools and techniques enabled by the semiconductor revolution.

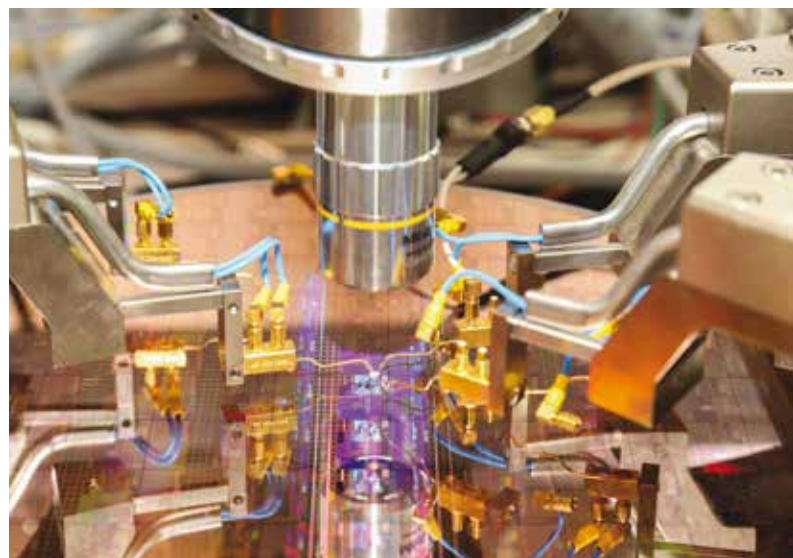
This emerging field, known as integrated photonics, attempts to replicate the semiconductor business model in the field of photonics (a subfield of optics focusing on the interaction of photons and electronics). To accomplish this, researchers have continued focusing on miniaturizing optical elements by fabricating them using standard wafer-level processing tools. This also simultaneously reduces cost (integrated photonics thus refers to the use of semiconductor processing techniques to

realize photonics systems). The remaining assembly steps, such as attaching optical fibers to a packaged part, will necessitate the creation of new, or dramatic redesign of existing, microelectronics assembly tools. Today, packaging and assembly are the most significant cost contributors to manufacturing photonics products.

The implementation and application of integrated photonics already has begun with emerging use in telecommunications and more recently data centers, in which communication between server racks has migrated to fiber transmission. This transition is expected to progress as copper cables of shorter and shorter distances are replaced with optical fibers leveraging integrated photonic circuit based transceivers on their ends. It is also anticipated that integrated photonics will be leveraged by several additional industry segments to address needs in microwave, array and sensor applications.

The impact of photonics over the next 20 years will reach across all spectrums—from defense, space and communications, to driverless vehicles, advanced drone applications and consumer applications. For example, LIDAR (a laser-based implementation of radar used to extract distance information) for automotive, body sensing and holographic user interfaces are all disruptive photonic technologies that should change how people commute, interface and communicate in the near future.

The greatest challenge for all these technologies is taking them from proof of concept to commercialization. This challenge provided the impetus for the creation of the American Institute for Manufacturing of Integrated Photonics: AIM Photonics.



At right , another view of work in the clean room used by AIM. Above, a silicon wafer being examined under magnification.

The Institute's Mission and Vision

Established in 2015, AIM Photonics is a manufacturing innovation institute headquartered in New York. As a Manufacturing Institute funded by the Department of Defense, the mission of AIM Photonics is to enhance the maturity of the U.S. integrated photonics industry by developing and deploying manufacturing technologies. The institute will focus on four primary areas of manufacturing technology that were identified as key hurdles to widespread adoption on integrated photonics:

- Electronic and photonic design automation
- Multi-project wafer processing and packaging
- Inline control and test
- Test, assembly and packaging

The development of these capabilities will promote the maturation of manufacturing around key technologies, thereby enabling rapid photonic development through proof of concept, validation, qualification and commercialization under one national institute, ensuring manufacturing advancements for years to come. In addition, AIM Photonics will support hardware builds via a multi-project-wafer service and offer capacity to meet governmental and industrial needs for early user hardware.

To validate advances made in the manufacturing technologies and to support industrial members, the institute will develop and demonstrate innovative manufacturing technologies for:

- Ultra-high-speed transmission and switching of signals for the Internet, telecommunications and datacenters
- Integrated microwave photonic circuits (using light to transmit and process optical signals encoded with analog information at frequencies in the gigahertz regime)
- Sensor applications including chemical and biological sensors, navigation sensors and other sensor types/topics
- Applications requiring the formation of arrays of components (e.g., the LIDAR application noted above)

As it develops these technologies, AIM Photonics will maintain a focus on providing state-of-the-art capabilities by integrating traditional photonic technologies with advanced nanotechnology transistors on a silicon wafer fabricated using a standard silicon foundry process. This effort will decrease cost, reduce the time to market, and alleviate market entrance challenges for all members of the photonics community.

AIM Photonics is supported by a significant number of large, medium and small companies, as well as several states, notably New York, California, Massachusetts and Arizona. The state of New York, in particular, has committed substantial financial resources to build new manufacturing research and development capabilities to support this Institute. These funds also will be used to improve upon existing state-of-the-art infrastructure and capabilities within the state of New York. At its technical headquarters in Albany, New York, AIM Photonics boasts a fully integrated 300-millimeter silicon wafer capability that has been used extensively to support prior government and industry projects in integrated photonics. In addition to

the Albany facility, enhancements to enable broader access to processing capabilities for small and medium enterprises, AIM Photonics also has planned, and has now entered, the execution phase of an integrated photonics test, assembly and packaging facility in Rochester, New York. These two facilities will provide the backbone of the institute's capabilities, but satellite facilities at its partner locations in Santa Barbara, California, Tucson, Arizona, New York City, and Boston, Massachusetts, will add to this network additional key skills and capabilities critical to the Institute's long-term success. Photos of a silicon wafer containing electrical circuits and attached optical die and the 300mm cleanroom in Albany in which the wafer was built are shown on Pages 36 and 37.

terest to its stakeholders. Within the initial 4 months, AIM Photonics completed the first cycle of project selection and awards. Out of almost 50 project proposals submitted, our team of experts selected those that fit the goals of AIM Photonics and were compatible with the initial capabilities of our facilities. AIM Photonics now is entering its second annual cycle of project awards with a call for proposals having been announced in April.

Additionally, AIM has merged an integrated photonics roadmapping effort (sponsored by the National Institute of Standards and Technology) into its portfolio of projects and has launched an ambitious nationwide effort in education and

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Integrated photonics is being developed on indium phosphate- and silicon-based platforms, both of which will be available through the AIM Photonics Manufacturing Innovation Institute. Silicon photonics in particular has the potential to significantly reduce the cost of optical devices used in many traditional systems in addition to enabling new devices and applications. The availability of a state-of-the-art complimentary metal-oxide-semiconductor (CMOS) processing facility and infrastructure in AIM Photonics will allow efficient photonic integration. In addition, the ability to integrate photonic devices with CMOS electronics in a wafer-scale manner can greatly increase the capacity of integrated circuits and reduce the size, weight and power dissipation while simultaneously increasing the reliability of the systems employing these components. AIM Photonics also provides a variety of solutions for integrating the critical functionality of III-V materials, ranging from monolithic indium phosphide photonic integrated circuits to heterogeneous materials integration.

The AIM vision is to establish a domestic technology, business and education framework for industry, government and academia to accelerate the transition of integrated photonic solutions from innovation to manufacturing-ready deployment in systems spanning commercial and defense applications. The application spaces expected to be the first in which there is widespread commercial adoption are: high-speed digital photonics for data centers; high-speed analog photonic links for analog data remoting applications; and photonic sensors for the developing Internet of Things.

Launch of the Institute

During its first 9 months, AIM Photonics established a series of business processes for the roadmap-based development, submission, down-selection, and funding of projects of in-

terest to its stakeholders. This effort, titled the AIM Academy, will ensure that AIM Photonics provides the manufacturing readiness to build integrated photonics, and develops the requisite workforce to support such an integrated photonics ecosystem. AIM Photonics intends to provide the domestic industry with critically important skills ranging from technician and manufacturing-line operator to Ph.D.-level skills in design, test and process development with key instructional resources from notable universities such as the Massachusetts Institute of Technology, Columbia University, the University of Rochester, the University of California, Santa Barbara, and others. In parallel with the development of courses with stackable credentials across the range of educational needs, AIM Photonics also has embarked on a detailed industry study to identify which skills are required in which geographic region in order to best match needs to available skills.

A Truly Innovative Institute

The unique combination of education, training and technological innovation that AIM Photonics provides will help speed the domestic integrated photonics manufacturing industry into the future. With innovation around the manufacturing of integrated photonics, new technologies are being developed that will conserve energy in the manufacturing process and allow for unprecedented advances in novel applications.

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