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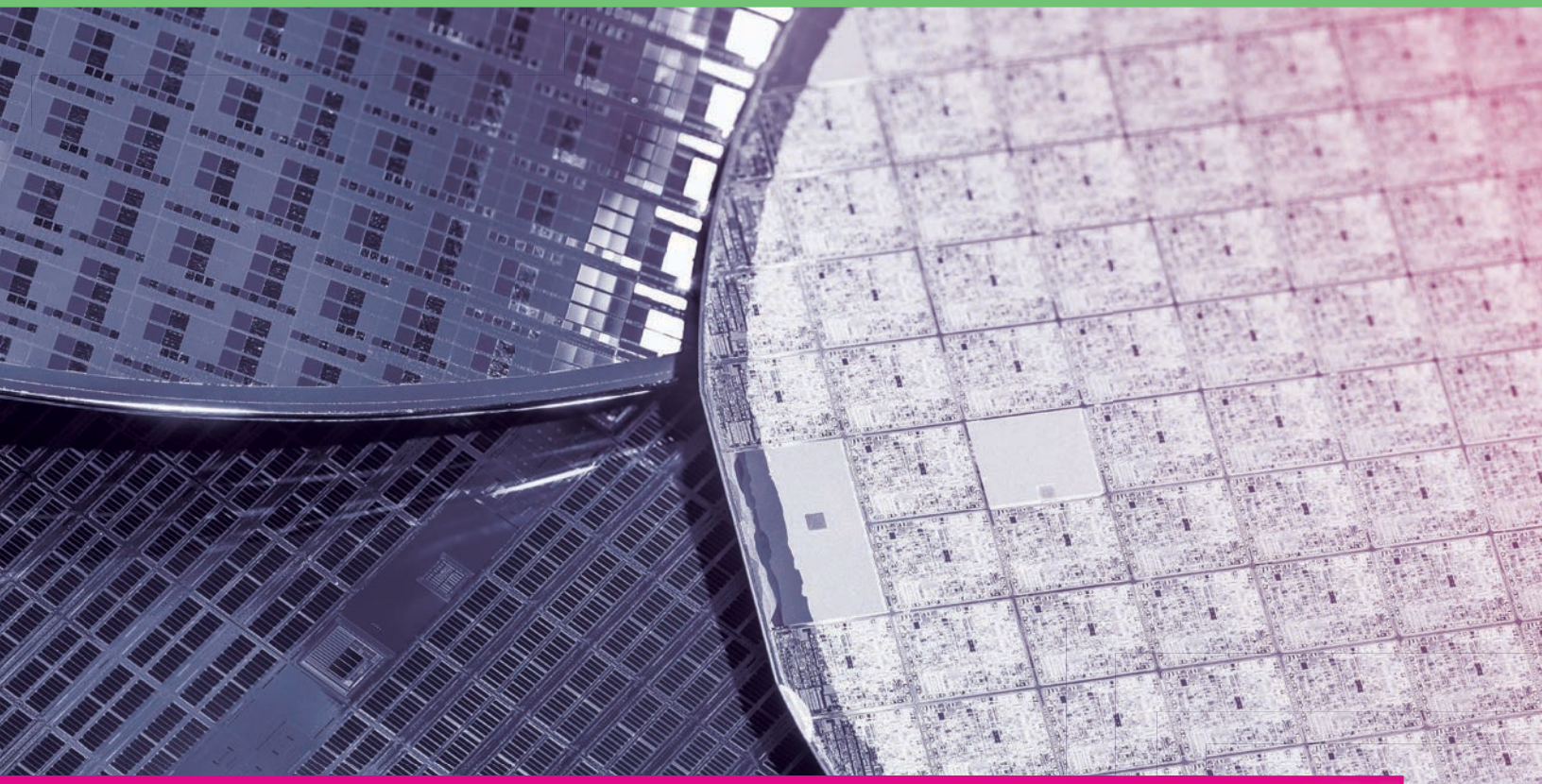

COMMERCIAL FABRICATION OF PHOTONIC INTEGRATED CIRCUITS: CHALLENGES AND OPPORTUNITIES FOR ENABLING QUANTUM TECHNOLOGIES

SEPTEMBER 2026

About the Quantum Economic Development Consortium
The Quantum Economic Development Consortium (QED-C) is the world's premier association of pioneers in the quantum technology marketplace. QED-C members enable real-world application of quantum technology and, in turn, help build a robust commercial industry and supply chain.

Sitting at the intersection of technology, academia, business, entrepreneurship, and policymaking, QED-C fosters the collaboration the industry needs. Its experts and organizations share knowledge and collectively shape the growth of quantum technology. QED-C is managed by SRI.

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- Constanza Vidal Bustamante, Center for a New American Security (Co-Chair)
- Michael Fanto, Department of War (Co-Chair)
- Saeed Pegahan, Modulight (Co-Chair)
- John Burke, Beacon Photonics
- Shayne De la Force, LFI
- Sebastian Engelmann, IBM
- Ella Lachman, Rigetti
- Melissa LaReau, International Trade Administration
- Evan Schlosser, International Trade Administration
- Sauli Sinisalo, Bluefors
- Chris Wood, QPICs

The following SRI staff contributed to this report:

- Ryan Nesselrodt, Jordan Bass, Brandon van Hoff, Annie Wyhof, Mary Beth Kelly, Jessica Avery, Lucien Randazzese, and Christiana McFarland, SRI Center for Innovation Strategy and Policy
- Celia Merzbacher, QED-C Executive Director
- Jonathan Felbinger, QED-C Deputy Director

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Executive Summary

Photonic integrated circuits (PICs) generate, direct, manipulate, and detect light to perform multiple functions on a single device and are widely recognized as a key enabling technology for quantum computing, sensing, timing, and networking. Commercial integrated photonics already support information transfer, processing, and other applications in telecommunications, digital technologies, and defense. However, existing commercial integrated photonics fabrication processes do not readily meet the requirements of the quantum industry. Quantum technologies require functions, wavelengths, materials, and loss tolerances that differ from those typically offered by commercial PIC fabrication processes serving established non-quantum markets, but some applications can use existing processes as a baseline.

Foundry operators that produce PICs have hesitated to invest in specialized processes for these quantum requirements because the relative immaturity of commercial quantum products and uncertainty about the scale of future quantum-relevant PIC demand make returns on investment slow and uncertain. Federal efforts to support regional quantum ecosystems and quantum-specific photonics fabrication seek to address these private market gaps. Several foundries, largely in Europe, are investing in quantum photonics processes and infrastructure in anticipation of greater demand. Some quantum computing companies are pursuing vertical integration by acquiring existing foundries to gain greater control over technology and production.

This report explores how the role and fabrication requirements of PICs vary across quantum technologies, the commercial integrated photonics fabrication landscape and its near-term relevance to scaling quantum photonics, bottlenecks to moving quantum photonic devices from the laboratory to fabrication, and regional quantum photonics initiatives. It concludes with six recommendations to strengthen integrated photonics fabrication for scaling quantum technologies:

- Explicitly include photonics fabrication considerations in quantum supply-chain analyses.
- Sustain and expand heterogeneous integration research and development.
- Expand or establish rapid-cycle, quantum-first fabrication and packaging capacity.
- Support manufacturing readiness and strengthen lab-to-fab process-transfer pathways for quantum-relevant PICs.
- Structure investment in shared photonics-fabrication infrastructure for broad access and multiuse value.
- Strengthen regional manufacturing transition networks and specializations.

As artificial intelligence drives demand for integrated photonics in data centers, targeted federal and private action could build photonics capacity relevant to quantum technologies, another federal critical-technology priority. Quantum computing, sensing, timing, and networking could benefit from investments that expand the capability to fabricate, integrate, package, and test photonic technologies to meet the demands of quantum applications.

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Introduction

Photonic integrated circuits (PICs) enable a range of quantum applications. PICs generate, direct, manipulate, and detect light, as an electromagnetic wave or individual photons, to perform a variety of information processing, measurement, and other functions. As quantum devices move from laboratory demonstrations to deployable systems, quantum-relevant PIC fabrication must become more repeatable, less expensive, more accessible, and better able to combine multiple materials and functions in one device.

This report provides an overview of commercial PIC fabrication capabilities relevant to quantum technologies, focusing on the capabilities and manufacturing pathways available to U.S. companies and researchers. Because most available information concerns PICs serving established commercial and industrial markets, the discussion of the commercial landscape draws largely on the broader PIC industry, while calling out quantum-relevant capabilities, requirements, and developments where applicable. It examines available material platforms, device types, integration approaches, production capabilities, and the roles of mid-scale providers and large foundries in prototype development, pilot production, and manufacturing scale-up. It also identifies technical, operational, and ecosystem factors that aid or impede the transition from research fabrication to commercial production.

This report does not benchmark individual fabrication facilities or evaluate proprietary vendor capabilities. Advanced packaging, assembly, and testing are considered only as needed to understand the fabrication, integration, and manufacturing scale-up of quantum-relevant PICs, but the report does not comprehensively assess the broader packaging, assembly, or testing industries. Algorithms, applications, and end-user adoption are similarly outside the scope of this report, except where they influence PIC fabrication requirements or manufacturing demand.

The Quantum Economic Development Consortium (QED-C) conducted this assessment through a multiphase process. The study began with a framing and scoping phase that set the objectives, framing questions, scope boundaries, and intended audiences in consultation with an ad hoc working group of members of the QED-C Enabling Technologies Technical Advisory Committee. The research phase included a landscape analysis of commercial fabrication providers, manufacturing capabilities, public-sector initiatives, policy developments, and broader trends in the photonics and semiconductor ecosystems. It also included interviews with subject matter experts from industry, academia, government, and related organizations. These interviews validated findings, clarified technical and operational challenges, and identified bottlenecks affecting quantum-relevant PIC fabrication scale-up. The working group reviewed the draft and convened stakeholders to inform the final report. See Appendix 1: Workshop Agenda and Appendix 2: Workshop Participant List for the stakeholder meeting agenda and participant list.

The remainder of this introduction provides a brief primer on integrated photonics, including current commercial uses and the value for quantum technologies. The importance of PICs to scaling and their fabrication requirements vary by qubit modality (see Figure 1: Role and Importance of PICs to Scaling by Qubit Modality). This variety of stringent fabrication requirements, alongside small quantum-specific demand, helps illustrate why existing semiconductor and commercial PIC fabrication capacity cannot

immediately be used to fabricate quantum-relevant PICs without modification.[1] This tension underlies the remainder of this report, policy actions such as the administration's Executive Order 14413: "Ushering in the Next Frontier of Quantum Innovation," and the recommendations that follow.

Commercial PIC Primer

Like semiconductor integrated circuits, PICs transmit data, make measurements, or perform computations; however, they use light rather than electrons. Within a single device, PICs can generate photons; direct them along desired paths; manipulate properties such as intensity, phase, and wavelength; and detect them.

The performance of a PIC depends on the materials used to fabricate it. Unlike semiconductor electronics, which rely heavily on silicon, integrated photonics has no single material platform that performs every needed function.[2] Some materials are better for passive functions such as low-loss waveguides, whereas others, including III-V semiconductors, are needed for active functions such as light generation.[3] Wavelength also matters: many quantum systems use visible light, whereas mature telecommunications PIC platforms were built mainly for infrared wavelengths.[4]

Commercial integrated photonics were first developed for telecommunications, with PICs converting between electronic and optical signals for high-speed, long-distance fiber-optic networks.[5] Data centers now rely on PIC-based optical transceivers to move data efficiently between servers and switches. Artificial intelligence (AI) workloads are increasing demand for higher-bandwidth, lower-power optical links.[6] PICs support Light Detection and Ranging (LIDaR), navigation, positioning and timing, secure

[1] For a more detailed technical explanation of the role of PICs in quantum technology, see Appendix 4: Quantum-Relevant PIC Fabrication Requirements and QED-C, *Photonic Integrated Circuits for Quantum Applications: Challenges and Opportunities* (SRI International, November 2023), https://quantumconsortium.org/PICs23.

[2] Meint Smit *et al.*, "An Introduction to InP-Based Generic Integration Technology," *Semiconductor Science and Technology* 29, no. 8 (2014): 083001, https://iopscience.iop.org/article/10.1088/0268-1242/29/8/083001; Constanza M. Vidal Bustamante and John Burke, *Quantum's Industrial Moment: Strengthening U.S. Quantum Supply Chains for Scalable Advantage* (Center for a New American Security, March 2026), https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/Quantum_TECH_260311_Final-D.pdf; QED-C. *Photonic Integrated Circuits for Quantum Applications*.

[3] D. Liang and J. E. Bowers, "Photonic Integration: Si or InP Substrates?" *Electronics Letters* 45, no. 12 (2009), https://web.ece.ucsb.edu/uoeg/publications/papers/liang09EL.pdf.

[4] Daniel J. Blumenthal *et al.*, "Silicon Nitride in Silicon Photonics," *Proceedings of the IEEE* 106, no. 12 (2018): 2209–31, https://doi.org/10.1109/JPROC.2018.2861576. See QED-C's 2023 report *Photonic Integrated Circuits for Quantum Applications* for a more detailed description of common platforms and existing technical challenges, including the "rainbow problem"—the difficulty of multiwavelength operation on a single platform.

[5] Chong Zhang *et al.*, "Integrated Photonics Beyond Communications," *Applied Physics Letters* 123, no. 23 (2023): 230501, https://doi.org/10.1063/5.0184677. Long-distance quantum communications will be carried through existing telecommunications fiber optic networks, an additional place where telecommunications fabrication infrastructure can help to advance quantum technology.

[6] Geoff Tate, "Silicon Photonics in the Data Center: What a CMOS Exec Needs to Know," *Semiconductor Engineering*, February 9, 2026, https://semiengineering.com/silicon-photonics-in-the-data-center-what-a-cmos-exec-needs-to-know/.

communications, and other defense applications.[7] These established markets have built supplier bases and manufacturing infrastructure that quantum technologies can build on in some cases.[8]

Commercial PIC fabrication operates at lower production volumes and is less standardized and more fragmented than conventional semiconductor fabrication.[9] Quantum-relevant processes are especially immature, particularly for the submicron wavelengths many quantum systems require.[10] Because no single material platform can perform every function required, PIC designs often combine different materials and functions in one device (heterogeneous integration) and require custom electronics. Packaging and integration make up a larger share of device cost than front-end fabrication.[11] Process design kits, libraries of basic photonic components, can differ between foundries, complicating design and process transfer.

The integrated photonics and semiconductor ecosystems overlap in important ways, but that overlap does not mean existing semiconductor foundries can readily support quantum-relevant PIC development. Silicon photonics can benefit from semiconductor infrastructure and demand from data centers and AI. However, many quantum-relevant platforms, including thin-film lithium niobate, diamond, and III-V quantum emitters, are not readily compatible with complementary metal-oxide-semiconductor (CMOS) fabs and have technical requirements beyond those of existing commercial integrated photonics.[12] Scaling these technologies will likely require specialty PIC providers, mid-scale facilities, and foundries that can handle materials and integration needs outside standard semiconductor and commercial photonics workflows. For a comparison of the semiconductor and integrated photonics fabrication ecosystems, see Appendix 1: Workshop Agenda

QED-C convened a workshop on commercial fabrication of photonic integrated circuits for quantum technologies on July 30, 2026, at the Denver Athletic Club.

Time	**Session**
8:30 – 9:00 AM	Registration and Networking Breakfast
9:00 – 9:15 AM	**Welcome**
9:15 – 9:45 AM	**Assessment Overview** Preliminary findings from the QED-C Commercial PIC Fabrication Assessment
9:45 – 10:45 AM	**Panel Discussion: The Current State of Commercial PIC Fabrication** Perspectives from commercial foundries and industry on the current manufacturing landscape, capabilities, and challenges **Moderator:** John Burke – Beacon Photonic

[7] Sam Dale, "Photonic Integrated Circuits (PICs) in Healthcare, Quantum, and More," IDTechEx, April 11, 2025, https://www.idtechex.com/en/research-article/photonic-integrated-circuits-pics-in-healthcare-quantum-and-more/32993; "Photonic Integrated Circuits," NATO Science and Technology Organization, SET-331 Research Specialists' Meeting, Dresden, Germany, October 21–22, 2024, https://www.sto.nato.int/document/photonic-integrated-circuits/; Military + Aerospace Electronics, "DARPA Eyes Photonic Integrated Circuits for Non-GPS Position, Navigation, and Timing (PNT)," August 1, 2018, https://www.militaryaerospace.com/computers/article/16726508/darpa-eyes-photonic-integrated-circuits-for-non-gps-position-navigation-and-timing-pnt.

[8] "Technology," PsiQuantum, accessed June 18, 2026, https://www.psiquantum.com/technology.

[9] See appendix 3 for a direct comparison of fabrication in the two industries.

[10] Lucien Randazzese *et al.*, *Quantum Technology Manufacturing Roadmap: Scaling Up Quantum* (SRI International, October 2023), https://www.sri.com/wp-content/uploads/2023/11/QTMR-Final-Report-of-Needs-Capabilities-and-Gaps-v5.pdf.

[11] Drew Weninger *et al.*, "Advances in Waveguide to Waveguide Couplers for 3D Integrated Photonic Packaging," *Light: Science & Applications* 15 (2026): 17, https://doi.org/10.1038/s41377-025-02048-w.

[12] Xu Han *et al.*, "Breaking Dense Integration Limits: Inverse-Designed Lithium Niobate Multimode Photonic Circuits," *Nature Communications* 17, no. 1162 (2026), https://www.nature.com/articles/s41467-025-67927-7.

Time	Session
	○ **Shantanu Misra** – GlobalFoundries ○ **Robert Visser** – Applied Materials ○ **Brian Wilbur** – SkyWater Technology ○ **Vimal Kamineni** – PsiQuantum
10:45 – 11:00 AM	Break
11:00 AM – 12:00 PM	**Panel Discussion: Ecosystem Building Initiatives** Discussion of infrastructure investments, commercialization support, workforce development, and regional ecosystem development **Moderator:** Constanza Vidal Bustamante – CNAS ○ **Philip Makotyn** – IQMP ○ **Jessi Olsen** – Elevate Quantum ○ **Christopher Striemer** – AIM Photonics TAP Facility ○ **Ben Losby** – QCORE
12:00 – 1:00 PM	Lunch
1:00 – 1:45 PM	**Breakout Session 1: Transitioning from Research to Commercial Manufacturing**
1:45 – 2:00 PM	Breakout Report Out
2:00 – 2:15 PM	Break
2:15 – 3:00 PM	**Breakout Session 2: Manufacturing Bottlenecks and Capability Gaps**
3:00 – 3:15 PM	Breakout Report Out
3:15 – 3:30 PM	Break
3:30 – 4:15 PM	**Breakout Session 3: Prioritizing Investments and Policy Recommendations**
4:15 – 4:30 PM	Breakout Report Out
4:30 – 4:50 PM	**Workshop Synthesis and Discussion** Key themes, areas of consensus, and remaining questions
4:50 – 5:00 PM	Closing Remarks and Next Steps
5:00 – 6:00 PM	Reception • 3rd Floor Foyer, Denver Athletic Club

Appendix 2: Workshop Participant List

Jessica Avery, SRI International
Marcus Bagnell, SRI International
Jordan Bass, SRI International
Jennifer Black, Vescent Technologies
John Burke, Beacon Photonics
Zijun Chen, Lawrence Livermore National Laboratory
Patrick Chu, Sandia National Laboratories
Bryan DeBono, Quantinuum
Peter DeVore, Lawrence Livermore National Laboratory
Jonathan Felbinger, QED-C
Amirhossein Ghods, Mesa Quantum
Adam Heiniger, TOPTICA Photonics
Stephen Heinrich-Barna, Anametric, Inc.
Paul Juodawlkis, MIT Lincoln Laboratory
Vimal Kamineni, PsiQuantum
Christopher Kocot, Coherent Corp
Keisuke Kojima, Boston Quantum Photonics
Ben Losby, QCORE-Montana State University
Philip Makotyn, IQMP
Shantanu Misra, GlobalFoundries
Jessi Olsen, Elevate Quantum
Elliott Ortmann, Xanadu Quantum Technologies
Wil Oxford, Anametric, Inc.
Scott Papp, NIST
Saeed Pegahan, Modulight USA
Joanna Peters, StratConGlobal Inc.
Amirhassan Shams-Ansari, Monarch Quantum
Mark Stone, Atom Computing
Christopher Striemer, AIM Photonics TAP Facility
Brandon van Hoff, SRI International
Constanza Vidal Bustamante, Center for a New American Security
Robert Visser, Applied Materials
Brian Wilbur, SkyWater Technology
Chris Wood, QPICs
Annie Wyhof, SRI International

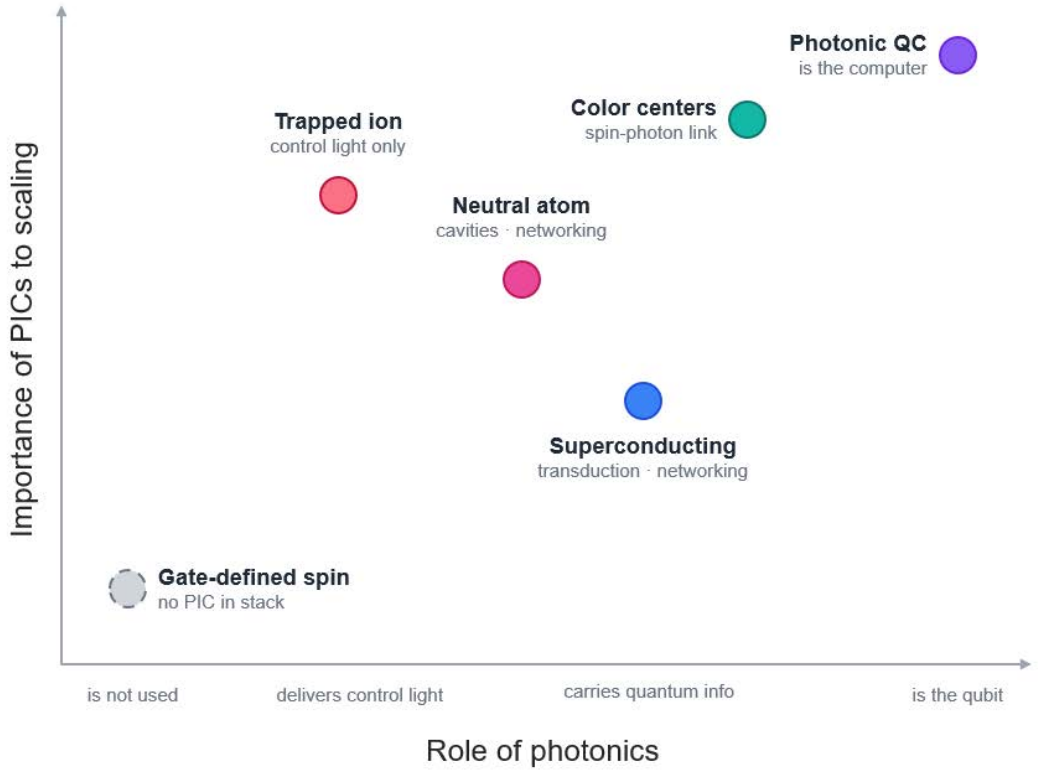
Appendix 3: Semiconductor and PIC Fabrication Comparison

PICs for Quantum Technologies

Quantum systems depend on the precise manipulation of light, making integrated photonics key to the scaling of quantum technologies.[13] Neutral atom and trapped ion systems use light to initialize, control, and read out qubits. Superconducting and spin systems may use optical links for networking. Photonic qubits use the PIC itself as the processor. Photons can also be used to connect different quantum modalities. As a result, nearly every quantum modality could benefit from denser, more rugged, and more repeatable integrated photonics even though the urgency and requirements differ by modality.[14]

Beyond quantum computing, PICs could enable integrated, scalable sensor networks to make sensitive measurements beyond the reach of classical sensor networks. Many quantum sensors also rely on the precise control of light offered by PICs to reduce SWaP-C (size, weight, power, and cost) and improve portability.

Figure 1: Role and Importance of PICs to Scaling by Qubit Modality



Note: Each modality is positioned according to the role photonics plays during operation (horizontal) and how essential PICs are to scaling that modality (vertical). Dot color identifies the modality. Positions are notional.
Source: QED-C.

[13] QED-C, *Photonic Integrated Circuits for Quantum Applications*.
[14] Bustamante and Burke, *Quantum's Industrial Moment*, 14–15.

Quantum-relevant PIC fabrication differs from telecommunications and data communications fabrication in loss tolerance, operating wavelength, material compatibility, and integration complexity. Depending on the target modality, foundries may need to adapt existing processes or develop new integration methods. Because of these differences, rising commercial PIC demand from data center and telecommunications applications will not necessarily lead to foundry investment in the processes and capabilities most relevant for quantum-relevant PIC fabrication.

As figure 1 shows, the more central photonics are to a qubit modality, the more PIC fabrication matters to scaling. Photonic and color-center qubits are therefore most likely to encounter PIC fabrication as a binding constraint. Photonic qubits, which use photons as the information carriers, depend most directly on PIC fabrication capability and have the tightest requirements, including very low loss.

Trapped-ion qubits, by comparison, often have less strict loss requirements because the photons do not carry quantum information.[15] Better PIC fabrication could help trapped-ion systems scale by reducing the footprint and alignment challenge of free-space optical control. Neutral-atom systems could use PICs for both control and entanglement-enabled networking, which could help shrink the hardware footprint and scale these systems beyond a single chamber. For more on modality-specific PIC fabrication requirements, see Appendix 4: Quantum-Relevant PIC Fabrication Requirements.

Some fabrication requirements overlap. For example, low-loss visible and near-ultraviolet waveguides are needed by both trapped-ion and neutral-atom systems. Neither platform demands quantum-level loss performance from these waveguides, meaning that advances driven by any modality, or by non-quantum applications that also require visible wavelengths, would benefit multiple modalities. Strong light-modulating materials are relevant to photonic quantum computing, frequency conversion, and superconducting transducers. Improving etching quality, wafer-scale uniformity, and low-temperature device performance for any one of these applications would reduce barriers for the others. **Error! Reference source not found.Error! Reference source not found.**For more details on modality-specific fabrication requirements, see Appendix 4: Quantum-Relevant PIC Fabrication Requirements and the 2023 QED-C report on PICs.[16]

The variety of modality-specific roles played by PICs, combined with the immaturity of commercial quantum computing, means that demand for quantum-specific PICs is low. Experts interviewed for this report offer an optimistic five-year estimate of thousands of wafers per year. This relatively low demand makes it difficult for production foundries to justify investments in quantum-specific capabilities.

Governments have sought to address this challenge. The Air Force Research Laboratory (AFRL) and the Department of War have invested for years in AIM Photonics to help develop a manufacturable quantum-relevant PIC platform.[17] Executive Order 14413 ("Ushering in the Next Frontier in Quantum Innovation") mandates an updated national quantum strategy to address commercialization, manufacturing, and supply chain challenges. The Department of Commerce is also investing $375 million in GlobalFoundries to develop its quantum manufacturing capabilities.

Despite their differences, quantum-relevant PIC developers can draw on infrastructure and techniques from PICs developed for telecommunications and data communications and make investments that

[15] Although trapped-ion qubits have less stringent loss requirements for control light, operations such as on-chip entangling gates will require extremely low loss in the visible frequency range. These operations will be important for scaling atomic systems.

[16] QED-C, *Photonic Integrated Circuits for Quantum Applications*.

[17] "AIM Photonics," Department of War Manufacturing Technology Program, accessed August 24, 2026, https://www.dodmantech.mil/About-Us/Manufacturing-Innovation-Institutes-MIIs/AIM-Photonics/.

benefit multiple modalities. For example, improved transduction would benefit every qubit type except photonic qubits.[18] Improved frequency conversion would benefit many photonics applications, including photonic computing. Heterogeneous integration of light sources onto low-loss telecommunications routing platforms would help photonic quantum computing and color center systems.[19] This overlaps with ongoing telecommunications investment in III-V-on-silicon transceivers. Photonic quantum computing, color-center systems, and potentially neutral-atom systems need superconducting single-photon detectors.[20] Standard, foundry-compatible process steps to integrate these detectors more effectively would benefit all three modalities.

The remainder of this report outlines existing commercial integrated photonics fabrication capability, explores technical and economic bottlenecks to scaling quantum-relevant PIC fabrication, highlights regional initiatives aimed at addressing these challenges, and closes with recommendations.

Commercial Landscape of PIC Fabrication

This section characterizes the current commercial PIC fabrication landscape: what capabilities are available, where production scale remains limited, how companies access fabrication, and how providers fit into the path from prototype to production. Most available information concerns PICs serving established non-quantum markets, which currently account for the broadest commercial and industrial uses; quantum-relevant PICs are addressed where relevant. Since the 2023 QED-C report, public and private investment in the PIC industry at large has grown, driven largely by data center demand. Projections indicate the global market could grow from $17 billion in 2025 to $86 billion in 2034.[21] Meanwhile, quantum-relevant PIC demand remains important but small, not yet justifying large-scale fabrication investments on its own.[22] However, as traditional PIC manufacturing capabilities mature and the demand for integrated photonics for quantum technology grows, investment in quantum-relevant PIC production will likely increase to support evolving industry needs.[23]

Capacity and Scale

Common PIC platforms such as silicon nitride (SiN) and silicon-on-insulator (SOI) can be fabricated using CMOS-compatible processes with some modification, allowing them to take advantage of existing semiconductor manufacturing infrastructure as production scales. This will allow the PIC industry to scale more quickly as new chip fabs can require billions in equipment and facility costs, and require sufficient and predictable demand for viability.[24]

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[18] Transduction is the primary means by which PICs can help enable superconducting and spin-defined gate qubits scale. It is also an early-stage research problem that is in most cases relevant for quantum computing, with efficiencies too low for practical applications.

[19] Ali W. Elshaari *et al.*, "Hybrid Integrated Quantum Photonic Circuits," *Nature Photonics* 14, no. 5 (2020): 285–98, https://doi.org/10.1038/s41566-020-0609-x.

[20] Iman Esmaeil Zadeh *et al.*, "Superconducting Nanowire Single-Photon Detectors: A Perspective on Evolution, State-of-the-Art, Future Developments, and Applications," *Applied Physics Letters* 118, no. 19 (2021): 190502, https://doi.org/10.1063/5.0045990.

[21] Fortune Business Insights, *Photonic Integrated Circuit Market Size, Share & Industry Analysis*, last updated August 10, 2026, https://www.fortunebusinessinsights.com/photonic-integrated-circuit-market-107051.

[22] Robyn Laskey, "How Are Photonic Chips Used in Data Centers?," *PhotonDelta*, December 12, 2025, https://www.photondelta.com/blog/how-are-photonic-chips-used-in-data-centers/.

[23] QED-C, *Photonic Integrated Circuits for Quantum Applications*.

[24] Mark Lapedus, "Demand, Lead Times Soar for 300mm Equipment," *Semiconductor Engineering*, May 20, 2021, https://semiengineering.com/demand-lead-times-soar-for-300mm-equipment/.

Fab Production Volumes and Throughput

Public data on quantum-relevant PIC production is sparse, whereas data center and other non-quantum applications have driven recent growth in traditional PIC fabrication.[25] The clearest available evidence on quantum-relevant PICs comes from public datasheets on multi-project wafer (MPW) runs. These datasheets provide annual run counts for different materials and fabs, the number of dies provided, and service costs. Although they do not accurately measure the total capacity of a fab, they offer a limited proxy for that information.

Table 1 summarizes public MPW offerings from Cornerstone, AIM Photonics, and IMEC. It provides an overview of selected offerings rather than a direct facility comparison. The reported variables include the material platform and fab, die size, number of unpackaged chips, delivery time from application close to finished chips, and service cost. These factors define fundamental constraints for PIC designers. Additional factors such as wafer size and wafer stacks will influence costs, lead times, and delivery times across facilities. Most MPW runs provide only tens of chips per run, often have tight die-size constraints, take several months to complete, and offer several material options.

Table 1: Selected Fab Production Information

Company	Run Type	Die Size	Number of Chips	Delivery Time	Service Cost
Cornerstone (UK) [a]	MPW Ge-on-Si MPW	11.47 x 15.45 mm	5	10 weeks	£15,550 50% off for UK enterprises and academia
	MPW SiN 200nm-visible MPW w/ heaters		10	12 weeks	£19,980 50% off for UK enterprises and academia
	MPW SiN 200nm-visible MPW w/o heaters				£9,470 50% off for UK enterprises and academia
	MPW SiN 300nm MPW w/ heaters		10		£19,980 50% off for UK enterprises and academia
	MPW SiN 300nm MPW w/o heaters				£9,470 50% off for UK enterprises and academia
AIM Photonics (USA) [b]	MPW QFlex PIC	8 mm^2	20	7 months	$45,000 (member) $54,000 (nonmember)
		25 mm^2			$90,000 (member) $108,000 (nonmember)
		50 mm^2			$180,000 (member) $216,000 (nonmember)
		100 mm^2			$360,000 (member) $432,000 (nonmember)

[25] "Photonic Integrated Circuit Market Report 2030," Strategic Marketing Research, December 2025, https://www.strategicmarketresearch.com/market-report/photonic-integrated-circuit-market.

Company	Run Type	Die Size	Number of Chips	Delivery Time	Service Cost
IMEC (Belgium) [c]	Si-Photonics Passives+	Half block – horizontal (5.15mm x 2.5mm) or vertical (2.5mm x 5.15mm)	25	10 weeks	€6,700 standard €6,400 discounted
		1 block (5.15mm x 5.15mm)			€12,800 standard €12,100 discounted
		2 blocks – horizontal (10.45mm x 5.15mm) or vertical (5.15mm x 10.45mm)			€22,700 standard €21,500 discounted
	Si-Photonics iSiPP50G	Quarter block (2.5mm x 2.5mm)	25	9–10 weeks	€11,000 standard €10,500 discounted
		Half block – horizontal (5.15mm x 2.5mm) or vertical (2.5mm x 5.15mm)			€22,000 standard €21,000 discounted
		1 block (5.15mm x 5.15mm)			€44,000 standard €42,000 discounted

[a] "Live MPW Calls," Cornerstone, accessed July 6, 2026, https://cornerstone.sotonfab.co.uk/mpw/live-calls/.

[b] "Quantum Flex (QFlex) PIC," AIM Photonics, accessed July 6, 2026, https://www.aimphotonics.com/quantum-flex-pic.

[c] "2026 Run Schedules and Prices," EuroPractice IC Service, accessed August 6, 2026, https://europractice-ic.com/schedules-prices-2026/.

Development Process

This section outlines elements of the commercial development process for all PICs, from design and fabrication through assembly and packaging.

Design and Fabrication

PIC designers benefit from tools shared with the semiconductor industry, but each stage requires PIC-specific methods and libraries. PIC designers can use commercially available software for initial simulations and to prepare designs for fabrication. Design can be done in-house or through design

services, including those offered by fabrication facilities.[26] Common wafer materials include SiN, often used for LiDAR and SOI. Designers may also use materials such as gallium arsenide (GaAs), thin-film lithium niobate (TFLN), or indium phosphide (InP) for their photonic properties. Using these materials at larger silicon fabrication facilities presents wafer-size constraints and contamination risks. For fabrication, ultraviolet (UV) lithography and electron-beam lithography are the most common production methods, with imprint lithography showing potential as a faster, lower cost alternative.[27]

Integration, Assembly, and Packaging

Integrating, assembling, and packaging a PIC is currently the costliest stage of photonic device manufacturing.[28] Precise alignment requirements and limited packaging standards drive these costs as these stages involve combining photonic components and connecting them with optical, electrical, and other system elements. Two integration methods combine active and passive components on a single PIC device: hybrid integration and heterogeneous integration.

Hybrid integration manufactures the active and passive components of a PIC separately and combines them during packaging, ensuring the precise alignment of optical components and coupling. Although slower and more expensive, this method allows for greater flexibility with complex systems. Heterogeneous integration involves directly bonding or growing the passive and active materials together earlier in the production process. This method could reduce costs for volume production, but it also requires more sophisticated manufacturing capabilities.[29]

Packaging a commercial device, which sometimes requires custom control electronics and shielding, remains challenging. The lack of industry standards means that solutions are customized and driven by cost and capability considerations. Factors that influence packaging decisions include how PICs interface with traditional external electronics, environmental and thermal requirements, and optical alignment and fiber bundling methods.[30] Packaging techniques vary widely. Common approaches include compact transistor outline can (TO-can) packages, box-type packages, and butterfly packages. Many PICs serving established non-quantum applications use simple, low-cost, box-type packaging, whereas quantum photonics often uses butterfly packages for tighter thermal control.

Access Models

Many prominent fabrication facilities, including AIM Photonics, IMEC, GlobalFoundries, Tower, and LIGENTEC, can produce traditional and sometimes quantum-relevant PICs at their facilities. These fabs differ widely in their design and offerings and consequently meet different needs in the PIC ecosystem.

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[26] Robyn Laskey, "What Software Do You Need to Design Photonic Chips?" *PhotonDelta*, April 17, 2026, https://www.photondelta.com/blog/what-software-do-you-need-to-design-photonic-chips/.
[27] Robyn Laskey, "How Are Photonic Chips Manufactured?" *PhotonDelta*, January 5, 2026, https://www.photondelta.com/blog/how-are-photonic-chips-manufactured/.
[28] PhotonDelta, "As the PIC Ecosystem Grows, So Grows the Future Prospects for PICs," May 2, 2025, https://www.photondelta.com/news/as-the-pic-ecosystem-grows-so-grows-the-future-prospects-for-pics/.
[29] Robyn Laskey, "What Is the Difference Between Active and Passive Photonic Chips?" *PhotonDelta*, March 20, 2026, https://www.photondelta.com/blog/what-is-the-difference-between-active-and-passive-photonic-chips/.
[30] PhotonDelta, "As the PIC Ecosystem Grows"; Rüdiger Paschotta, "Photonic Packaging," in *The RP Photonics Encyclopedia*, accessed July 6, 2026, https://www.rp-photonics.com/photonic_packaging.html; "Volume packages," PHIX Photonics Assembly, accessed July 6, 2026, https://www.phix.com/our-offering/volume-package/; "Photonic Integrated Circuit Packaging and Assembly," LioniX International, accessed July 6, 2026, https://www.lionix-international.com/photonics/pic-technology/assembly-and-packaging-service/.

The variety of available process technologies, lead times, and prices drives a designer's choice of foundry.

Types of Manufacturing Runs and Scale

Foundries follow four major business models, distinguished by their accessibility to external customers. A user facility is a small, open, shared facility that supports the transition from basic research to small-scale commercial production methods. A pure-play foundry is a commercial facility whose core business model is producing chip components for external parties; pure-play foundries sell their fabrication services, not chips. A partial-play foundry produces and sells chips but also offers fabrication services to external customers. A captive foundry is a fabrication facility that exclusively produces chips for the company that owns the facility.

The four major semiconductor manufacturing run types are small-batch manufacturing, MPW, high-mix low-volume / high-mix high-value manufacturing, and high-volume manufacturing. PIC production spans all four run types, whereas quantum-relevant PIC production remains primarily in the small-batch category with limited MPW runs. Table 2 provides a description of each run type, in ascending order of volume.

Table 2: Manufacturing Run Types

Run Type	Description
Small-batch manufacturing	Small-batch manufacturing is an experimental production run and is the first step in developing a useful component. This approach usually occurs in user facilities. It primarily provides design and physics validation.
Multi-project wafer (MPW) runs	MPW runs are small production runs of chips. In this process, multiple companies share a wafer and have their designs produced side-by-side for a reduced cost. This process is performed at user facilities, partial-play foundries, and pure-play foundries. It does not include all manufacturing steps, such as assembly or packaging.
High-mix low-volume / high-mix high-value manufacturing	Like MPW runs, high-mix, low-volume production places specialized components from multiple companies on one wafer, but also provides final production steps such as assembly and packaging.
High-volume manufacturing	High-volume manufacturing is the highest volume form of component manufacturing. A single company typically uses a full wafer for one component. This mature production model offers the greatest economies-of-scale.

Roadblocks to Development

Like all manufacturing processes, the main challenges in developing PICs for quantum applications are the cost of development, lead times from order placement to chip delivery, and design constraints stemming from the requirements and intended use of the components.

Cost

Component costs depend largely on production scale, design specifications, and foundry choice. Depending on the number of chips that need to be produced, designers must select the manufacturing scale that best fits the project. In addition, design specifications such as chip size, materials, and complementary components added during assembly and packaging will increase the costs of chip production. Once volume and specifications are set, designers can choose a foundry.

Lead Time

Lead time is the period between order placement and delivery of the final chips. For both PICs serving established non-quantum markets and quantum-relevant PICs, lead time is difficult to estimate because it depends on factors such as chip complexity, chip size, and foundry choice. Public MPW schedules provide the clearest insight into lead times for quantum devices. Publicly available schedules reveal wide variation among fab offerings. MPW run timing can range from three and a half weeks to seven months.[31] If PIC production comes to resemble electronic component production, lead times may approach the current average of twelve to twenty-six weeks for traditional semiconductors.[32] Lead times remain a challenge for developers as they delay iteration cycles and innovation.

Production Constraints

Production constraints depend on chip design, fabrication access, and supply chain risks. The capabilities of different wafer materials affect the commercial and quantum applications a PIC may have and can impose specific operating conditions on the resulting PIC. Additionally, certain designs may only be producible with certain fab partners due to technology access, limiting who a designer can work with. Key material platforms like TFLN, InP, and GaAs are often sourced in part or whole from single sources or a handful of suppliers, often located in China. Trade disruptions can make accessing these materials difficult or costly.[33] Dedicated quantum-first fabrication and packaging facilities are also limited, though some providers are actively developing these capabilities. Because current demand is limited for highly specialized quantum-relevant PICs, most fabrication and packaging capabilities are dedicated to producing higher value, higher volume products for telecommunications or other industries. This constraint slows development cycles and increases costs for quantum-relevant PIC developers.

Key Fabrication Providers and Roles

Since the 2023 QED-C PICs report, the landscape of PIC packaging and foundry facilities has changed substantially. Appendix 5: Notable Packaging and Foundry Facilities Updates Since 2023 summarizes acquisitions, major investments in service providers, and new facilities. Although there is no industry-wide consensus on definitions, we discuss three scales of PIC production: university/lab-scale, mid-scale, and large-scale.

Provider Scales

University/lab-scale providers are primarily focused on research and development. They perform early development and prototyping for quantum-relevant PICs and PICs serving non-quantum markets alike. Mid-scale providers are the entry point to commercial scale fabrication. These providers face limits in equipment and capabilities but can standardize production methods for small to medium volumes of chips at reasonable costs, and follow established industry practices. Large-scale providers typically use

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[31] "Advanced Photonic Solutions & Services," LIGENTEC, accessed July 6, 2026, https://www.ligentec.com/offering/; "Quantum Flex (QFlex) PIC," AIM Photonics, accessed July 6, 2026, https://www.aimphotonics.com/quantum-flex-pic.

[32] Electronics Sourcing, "Understanding Lead Times," April 14, 2025, https://electronics-sourcing.com/2025/04/14/understanding-lead-times/.

[33] Quantum Computing Inc., "Thin Film Lithium Niobate (TFLN)," May 15, 2026, https://quantumcomputinginc.com/learn/research-and-publications/thin-film-lithium-niobate-tfln; Mika Takahashi, "Shifting Supply Chains in the Era of Photonics," *Photonic Integrated Circuits* 2026, no. 2 (2026): 26–30, https://picmagazine.net/article/124176/Shifting_supply_chains_in_the_era_of_photonics; Matthew P. Funaiole *et al.*, *De-Risking Gallium Supply Chains: The National Security Case for Eroding China's Critical Mineral Dominance* (Center for Strategic & International Studies, August 2023), https://www.csis.org/analysis/de-risking-gallium-supply-chains-national-security-case-eroding-chinas-critical-mineral; Laurie Chen and Liam Mo, "China's Control over Indium Phosphide Exports Threatens AI Data Centre Rollout," *Reuters*, June 10, 2026, https://www.reuters.com/world/china/chinas-control-over-indium-phosphide-exports-threatens-ai-data-centre-rollout-2026-06-11/.

advanced fabrication equipment and technologies to produce large chip volumes, and follow industry practices.

For quantum-relevant PICs, most production still occurs at the university/lab scale and is likely years away from higher volume commercial production. Quantum lab-scale offerings are most often through dedicated engagements with commercial partners like GlobalFoundries or federal production facilities such as the NSF Quantum Foundry at UC Santa Barbara, MIT's Lincoln Labs, or several other federal facilities.[34] Quantum mid-scale production is offered by pure-play foundries such as LIGENTEC, and large-scale quantum production has been reported by PsiQuantum at its captive foundry, but this is a rare exception to the typical scale of quantum-relevant PICs.[35] University/lab-scale facilities offer their own pathways for engaging with commercial partners, as indicated in their public-facing platforms.

Stringent quantum fabrication requirements, limited existing commercial applications, and the lack of a single quantum photonic platform (see Appendix 4: Quantum-Relevant PIC Fabrication Requirements) currently limit the industry's ability to scale quantum-relevant PIC production to mid- or large-scale levels or support dedicated fabrication facilities in the near term.

Ecosystem Growth

Market application and customer demand determine whether a PIC component or design advances from a prototype to commercial product. Government intervention can support growth, but it is less sustainable than a viable market. PIC use in established non-quantum markets continues to grow because they offer tangible benefits over legacy equipment. In networking, they lower power consumption, reduce latency, and improve network resiliency.[36] These applications increase demand and help move PIC technologies serving these markets from the lab and MPW runs at pure-play foundries. Quantum-relevant PICs, however, still lack a large market application and face technical challenges that slow movement along the same commercialization pathway.

Demand in related industries also affects the PIC industry. Recent fab and component acquisitions include IonQ acquiring SkyWater Technology, Quantum Computing Inc. acquiring Freedom Photonics and EM4, and GlobalFoundries acquiring Advanced MicroFoundry. These changes will reshape PIC production by altering market dynamics, shift facilities from pure-play to the partial-play or captive foundry models, and reduce the number of potential fabrication partners.[37] These changes raise

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[34] Amanda Morris, "First Electronic-Photonic Quantum Chip Manufactured in Commercial Foundry," *Northwestern Now*, July 14, 2025, https://news.northwestern.edu/stories/2025/07/first-electronic-photonic-quantum-chip-manufactured-in-commercial-foundry; "UCSB NSF Quantum Foundry," UC Santa Barbara Quantum Foundry, accessed July 6, 2026, https://quantumfoundry.ucsb.edu/; "Electronic-Photonic Integration Facility," MIT Lincoln Laboratory, accessed August 25, 2026, https://www.ll.mit.edu/about/facilities/electronic-photonic-integration-facility.

[35] LIGENTEC, "Advanced Photonic Solutions & Services"; PsiQuantum, "PsiQuantum Announces Omega, a Manufacturable Chipset for Photonic Quantum Computing," February 26, 2025, https://www.psiquantum.com/news-import/omega.

[36] Brad Smith, "A New Era in Data Center Networking with NVIDIA Silicon Photonics-Based Network Switching," Nvidia Developer, March 27, 2025, https://developer.nvidia.com/blog/a-new-era-in-data-center-networking-with-nvidia-silicon-photonics-based-network-switching/.

[37] IonQ, "IonQ to Acquire SkyWater Technology, Creating the Only Vertically Integrated Full-Stack Quantum Platform Company," January 26, 2026, https://www.ionq.com/news/ionq-to-acquire-skywater-technology-creating-the-only-vertically-integrated-full-stack-quantum-platform-company; "Luminar to Sell Photonics Subsidiary to Quantum Computing Inc. in $110M

concerns about commercial access, greater reliance on Chinese or European manufacturing, and U.S. leadership in PICs.[38]

A key milestone for any industry is sustained production. For PICs serving telecommunications, data-center, and AI markets, several companies conduct large-wafer, high-volume production for telecommunications and AI applications. An early mover, STMicroelectronics began producing its PIC100 platform on 300 mm wafers at scale with plans to quadruple production by 2027.[39] Additionally, HyperLight, UMC, and Wavetek jointly announced a high-volume TFLN Chiplet platform on 150 mm and 200 mm wafers.[40] Other companies, such as GlobalFoundries since its acquisition of AMF, have begun production, whereas Coherent has begun preparing fabs to produce at this scale if demand warrants.[41] MPW runs remain the primary manufacturing run type for quantum-relevant PICs, however organizations such as QPICs seek to become mid-scale providers and support sustained low-volume, customizable quantum photonics production.

Bottlenecks to Scaling PIC Fabrication for Quantum Applications

The core barrier to commercial-scale integrated quantum photonics is a mismatch between small, uncertain quantum demand and stringent technical requirements. Foundries need a path to sufficient volume before investing in quantum-specific technology and processes, whereas quantum companies need reliable fabrication before they can finalize a commercial device design. This tension is the central bottleneck and creates a set of interconnected economic, technical, and manufacturing challenges, summarized in figureFigure 2.

This assessment found no evidence that large numbers of mature quantum-relevant PIC designs await commercial foundry capacity. Instead, the constraint arises earlier in the commercialization pathway: demand for commercial quantum photonics products is limited. Mature silicon photonics fabs serve data communications and telecommunications markets, whereas universities and national laboratories create novel quantum photonic devices. Commercial facilities provide reproducibility and scale; research facilities provide rapid iteration and customization. Scaling quantum-relevant PICs requires a clearer path from research prototyping to reproducible commercial production. Bridging these environments is a challenge, requiring intermediate capabilities to support rapid iteration and pilot production, together with processes that allow successful designs to transfer to commercial manufacturing.

Deal," *Photonic Integrated Circuits*, December 16, 2025, https://picmagazine.net/article/123159/Luminar_to_sell_photonics_subsidiary_to_Quantum_Computing_Inc_in_110M_deal; Freedom Photonics, "Freedom Photonics Joins Quantum Computing Inc., Advancing Integrated Photonic Systems," February 2, 2026, https://freedomphotonics.com/news/freedom-photonics-joins-quantum-computing-inc-advancing-integrated-photonic-systems/; EM4, "EM4 Joins Quantum Computing Inc., Strengthening Vertically Integrated Photonics," February 2, 2026, https://em4photonics.com/news/em4-joins-quantum-computing-inc-strengthening-vertically-integrated-photonics/; GlobalFoundries, "GlobalFoundries Acquires Advanced Micro Foundry, Accelerating Silicon Photonics Global Leadership and Expanding AI Infrastructure Portfolio," November 18, 2025, https://gf.com/news-and-events/news/globalfoundries-acquires-advanced-micro-foundry-accelerating-silicon-photonics-global-leadership-and-expanding-ai-infrastructure-portfolio/.

[38] Bustamante and Burke, *Quantum's Industrial Moment*.

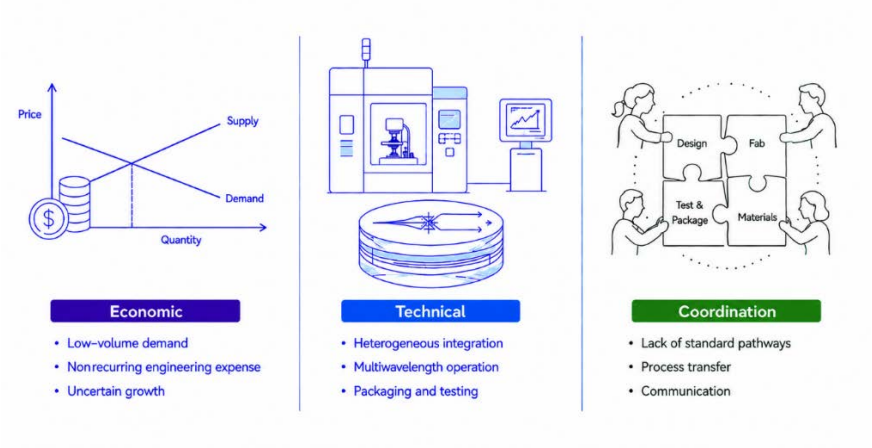
[39] STMicroelectronics, "STMicroelectronics Enters High-Volume Production of Its Industry-Leading Silicon Photonics Platform to Support AI Infrastructure Demand," March 9, 2026, https://newsroom.st.com/media-center/press-item.html/t4761.html.

[40] UMC, "HyperLight, UMC, and Wavetek Announce Strategic Partnership for High-Volume Foundry Production of TFLN Chiplet™ Platform," March 12, 2026, https://www.umc.com/en/News/press_release/Content/corporate/20260312.

[41] GlobalFoundries, "Silicon Photonics," accessed July 6, 2026, https://gf.com/technologies/silicon-photonics; Coherent Corp., "A CHIPS Letter of Intent for $50M to Expand World Leading Manufacturing Facility for AI Infrastructure," press release, June 16, 2026, https://www.coherent.com/news/press-releases/a-chip-letter-of-intent-for-50m-to-expand-world-leading-manufacturing-facility-for-ai-infrastructure.

These findings are consistent with a recent QED-C survey of the broader quantum community, in which fabrication, prototyping, and manufacturing emerged as the highest-priority capability to strengthen. The survey also identified fabrication and prototyping services and process development, reliability, and scale-up support among the most frequently reported unmet infrastructure needs.[42]

Figure 2: Barriers to Commercial Integrated Quantum Photonics



Source: QED-C

Economic and Business Model Barriers

As illustrated in Figure 2, the main economic barrier is demand. Foundries need reliable orders and a credible growth path before they devote space, staff, and capital to quantum-specific processes. At present, nonrecurring engineering costs must be funded to meet stringent loss and wavelength requirements before the market can support a return.

Quantum-relevant PIC demand is small and growth in demand is uncertain. Based on interviews for this report, optimistic demand over the next five years is thousands of wafers per year industrywide, across all quantum applications. By comparison, more than 80% of silicon photonics fabrication facilities surveyed between 2022 and 2024, reported producing more than 500 silicon photonic wafers monthly, or over 6,000 wafers annually.[43] At the high-volume end, SilTerra, a large foundry in Malaysia, is capable of producing 200 mm wafers at a rate of 46,000 per month.[44] At the low end of this estimate, anticipated quantum demand would occupy less than one day of production annually at a large-volume foundry such as SilTerra. At this scale, quantum demand alone does not yet justify quantum-specific process investments by major foundries.

Quantum-relevant PIC demand may grow as systems scale. Trapped-ion and neutral-atom systems can use tabletop optics today, but these setups become bulky and costly as qubit counts rise. Integrated photonics can reduce their footprint and support higher qubit counts. Quantum sensors may also add demand. It remains uncertain whether this demand will sustain reliable access to specialized fabrication

[42] QED-C, *Federally Funded Quantum Infrastructure Assessment: Recommendations for Federal Coordination and Investment* (QED-C, forthcoming).

[43] Market Growth Reports, *Silicon Photonics Wafer Foundry Market Size, Share, Growth, and Industry Analysis, by Type (300 mm Wafer, 200 mm Wafer, Others), by Application (Data Center, Non-Data Center), Regional Insights and Forecast From 2025 to 2035*, last updated December 1, 2025, accessed June 24, 2026, https://www.marketgrowthreports.com/market-reports/silicon-photonics-wafer-foundry-market-100327.

[44] "Manufacturing," SilTerra, accessed June 24, 2026, https://www.silterra.com/manufacturing/.

processes, or whether quantum photonics will need to rely on infrastructure and processes optimized for other, larger market applications.

Quantum computing companies are taking several approaches to this challenge. Large companies with access to capital are pursuing vertical integration, either by acquiring fabrication facilities outright (such as IonQ's $1.8 billion 2026 acquisition of SkyWater Technology, mentioned above) or by establishing dedicated quantum process lines within major foundries (such as PsiQuantum's partnership with GlobalFoundries).[45] Most startups cannot absorb the capital costs of a dedicated fab or codevelop custom process technologies. This disparity points to the value of openly accessible quantum-relevant PIC infrastructure, including MPW programs and facilities such as AIM Photonics that can serve a broad ecosystem and offer customizable quantum photonics platforms like AIM's Quantum Flex (QFlex) PIC.[46] GlobalFoundries' recent announcement that it is launching a "Quantum Technology Solutions" business supported by a $375 million award from the Department of Commerce could be a step toward expanding access.[47] However, limited public details make the scope and likely effect of this investment unclear.

Technical and Infrastructure Barriers

A central technical bottleneck is heterogeneous integration: efficiently combining different materials in one device to achieve the desired functions. This challenge affects both quantum photonic technologies and other PIC applications.[48]

University cleanrooms and national laboratory facilities develop novel photonic devices that require heterogeneous integration techniques. Researchers at Sandia's MESA facility have demonstrated heterogeneous integration of III-V materials, lithium niobate, and piezoelectric materials on various substrates, with a portfolio specifically focused on quantum photonics applications.[49] However, commercial facilities that provide multifunction, single-device photonic integration or hybrid integration at scale remain rare. In Europe, LIGENTEC has developed commercial processes for hybrid integration of TFLN and SiN on a single device.[50] Most commercial PIC companies and foundries, including HyperLight for TFLN and Smart Photonics for InP, still specialize in one material rather than combining two or more in one device.[51]

Rapid fabrication, packaging, and testing of multiwavelength, multifunction integrated photonic devices that meet stringent quantum requirements would help scale quantum computing and other applications. Qubit modalities operate across different parts of the spectrum; trapped barium ions, for instance, require control light in the visible and infrared bands, whereas photonic qubits generally operate in the infrared.[52] Quantum-relevant PIC fabrication processes therefore must be tailored to a

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[45] IonQ, "IonQ to Acquire SkyWater Technology"; "About," PsiQuantum, accessed June 24, 2026. https://www.psiquantum.com/about.
[46] AIM Photonics, "Quantum Flex (QFlex) PIC."
[47] Matt Swayne, "GlobalFoundries Launches Quantum Technology Solutions," *The Quantum Insider*, May 21, 2026, https://thequantuminsider.com/2026/05/21/globalfoundries-launches-quantum-technology-solutions/.
[48] Paramjeet Kaur *et al.*, "Hybrid and Heterogeneous Photonic Integration," *APL Photonics* 6, no. 6 (2021): 061102, https://doi.org/10.1063/5.0052700.
[49] "Sandia's National Security Photonics Center (NSPC)," Sandia National Laboratories, accessed June 18, 2026, https://www.sandia.gov/mesa/nspc/.
[50] "Technology," LIGENTEC, accessed June 24, 2026, https://www.ligentec.com/technology/.
[51] Lawrence Lundy-Bryan, "The Photonic Foundry Fallacy: The Biggest Opportunity in Computing," *State of the Future*, April 14, 2026, https://stateofthefuture.substack.com/p/the-photonic-foundry-fallacy.
[52] M. R. Dietrich *et al.*, "Barium Ions for Quantum Computation," *AIP Conference Proceedings* 1114 (2009): 25–30, https://doi.org/10.1063/1.3122286.

qubit modality; few investments in quantum photonics capabilities benefit the quantum industry broadly.

Material compatibility and thermal-budget constraints, particularly the incorporation of lasers and nonlinear optical materials into standard CMOS processes, present challenges. Emerging lower-temperature deposition methods, CMOS-compatible materials, and improved lithographic precision could reduce these barriers, although these solutions require further research. Greater heterogeneous integration capabilities would benefit a broader range of industries that rely on integrated photonics.

Much photonic integration today relies on hybrid methods that assemble separately fabricated components. Although effective at low and medium volumes, this approach does not scale efficiently.[53] Advances in wafer-scale integration could let manufacturers combine materials before dicing rather than after, improving throughput and scalability. The diversity of device platforms and uses has so far impeded standardized wafer-scale and device-scale characterization and testing protocols.

Facilities that characterize and test photonics devices are also scarce. AIM Photonics, a Manufacturing USA institute, operates the Test, Assembly, and Packaging (TAP) facility in Rochester, New York, the only site in the United States offering both photonic and electronic test, assembly, and packaging services for wafers up to 300 mm; before it opened in 2018, the United States had no open-access packaging facility at that scale.[54] Such facilities are expensive to maintain, and the number of interested users is relatively low. Some facilities also offer only a limited range of services. Intellectual property associated with a particular design often drives the selection of facilities for fabrication, testing, and packaging.

A lack of standardization affects the design phase as well. The design ecosystem is fragmented, and quantum companies may lack in-house photonics expertise. Individual fabrication facilities often have their own process design kits. Standard, well-qualified components with associated specifications, paired with a process design kit that simulates device performance, would help quantum companies and other users in designing, iterating on, and scaling integrated photonics devices. Although individual foundries have developed photonic process design kits, these generally support only one material, making simulation of multifunction photonic devices challenging or impossible.

This situation is evolving. Multimaterial process design kits would let quantum companies simulate integrated, multifunction PIC designs more accurately. AI design tools also allow less experienced designers to develop devices more quickly.[55]

Finally, packaging and assembly are critical to scaling quantum-relevant PIC production. As noted, high-efficiency fiber attachment is the main driver of packaging cost and can account for up to 80% of the total cost of a photonic device, compared with roughly 20% for a typical electronic semiconductor device.[56]

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[53] PhotonDelta, “Integrated Photonics Platforms Compared: Silicon Nitride, Indium Phosphide & Silicon Photonics,” March 8, 2023, https://www.photondelta.com/news/integrated-photonics-platforms-compared-silicon-nitride-indium-phosphide-silicon-photonics/.

[54] AIM Photonics, “AIM Photonics Announces New Opto-Electronic Testing Services,” accessed August 6, 2026, https://www.aimphotonics.com/news/opto-electronic-testing-services.

[55] "Work,” Boston Quantum Photonics, accessed August 6, 2026, https://www.bostonqp.com/.

[56] Nikolaus Flöry *et al.*, “Advancing the Semiconductorisation of Photonic Chip Packaging,” *Photonic Integrated Circuits* 2024, no. 4 (2024): 32–9. https://picmagazine.net/article/120689/Advancing_the_semiconductorisation_of_photonic_chip_packaging.

Transition Pathways from Prototype to Commercial Fabrication

Another obstacle for quantum companies seeking to transition a prototype photonic device to commercial production is coordination in a fragmented environment. No established pathways move a device from the prototype stage to annual production of 10, 100, or 1,000 wafers per year. University and government research programs and federally supported ecosystems such as the U.S. Economic Development Administration's Regional Technology and Innovation Hubs (Tech Hubs) program often rely on informal networks for the exchange of personnel, information, and products among laboratories and commercial foundries.[57] The Elevate Quantum Tech Hub in Colorado and New Mexico sponsors QPICs, a small, quantum-focused nano-fabrication facility under construction in Arvada, Colorado, that seeks to address the challenges of long lead times and mid-scale production for quantum photonic device fabrication.[58] The Headwaters Hub in Montana, focused on smart photonic sensor systems, is developing a concierge-style photonics advisory service.[59]

Existing foundry practices can help with the early stages of commercial production. MPW runs help at early design stages because companies do not require enough devices to fill an entire 200 mm or 300 mm wafer. However, MPW runs may only occur every six months, slowing cycle times and prototype iteration. This cadence can be too slow for startups that need to iterate quickly. All projects on an MPW must use the same layer stack, which provides a predictable fabrication timeline but restricts flexibility and experimentation in certain device designs.

Processes and production lines do not transfer easily from the laboratory to commercial fabs or between commercial fabs. Tool mismatch, lost tacit knowledge, and the need to redesign process recipes add time and cost to process transfers. Yield rates for photonic chips typically range from 30% to 70% even on a mature, stable process, and that variability often increases when a design moves to a new fab with different tools and operators.[60] As a result, initial foundry selection, including an assessment of capacity to scale, is especially important.

Interviews identified communication between device developers and commercial foundries as another transition bottleneck. Prototype developers often participate in every fabrication step and learn which processes are sensitive to small variations and which design tolerances can be relaxed without affecting performance. This tacit knowledge can be difficult to convey to a foundry team.

An emerging hub-and-spoke ecosystem for PIC design, fabrication, assembly, and packaging support is beginning to help close these gaps, but these efforts are at early stages and have not yet produced significant results. Efforts to increase access to rapid experimentation, quick design cycles, and scalable production could benefit quantum technology companies.

Multifunction photonic device fabrication capabilities could help scale emerging quantum technologies.[61] However, the stringent requirements of quantum devices require dedicated resources that are not currently justified by commercial demand alone.

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[57] "Regional Technology and Innovation Hubs," U.S. Economic Development Administration, accessed June 24, 2026, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs.
[58] "Elevate Quantum Tech Hub," U.S. Economic Development Administration, accessed June 24, 2026, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Elevate-Quantum-Tech-Hub.
[59] "Headwaters Hub," U.S. Economic Development Administration, accessed June 24, 2026, https://www.eda.gov/funding/programs/regional-technology-and-innovation-hubs/2023/Headwaters-Hub
[60] Robyn Laskey, "What Is the Yield Rate for Photonic Chip Manufacturing?" *PhotonDelta*, March 13, 2026, https://www.photondelta.com/blog/what-is-the-yield-rate-for-photonic-chip-manufacturing/.
[61] "About," National Quantum Initiative, accessed June 24, 2026, https://www.quantum.gov/national-quantum-initiative/.

Role of State and Regional Initiatives

States and regions across the United States have launched initiatives to support the development and commercialization of quantum technologies. Federal programs supporting regional technology development, advanced manufacturing, and commercialization, have helped drive this activity and will be discussed further in a forthcoming QED-C report. PICs have been a focus of many of these efforts because PICs can draw on existing semiconductor manufacturing capabilities and support a range of quantum applications.

This section focuses primarily on state, regional, and private-sector efforts to strengthen quantum and photonics manufacturing ecosystems, many of which are combined with federally funded programs and institutions. The discussion therefore includes federally supported entities and initiatives as needed for a complete picture but focuses on their role within the broader state or regional strategy.

State and Regional Case Studies

To strengthen regional quantum ecosystems, states and regions use a variety of tools, including investments in shared fabrication and testing infrastructure, commercialization support for emerging companies, tax incentives to attract private investment, workforce training programs, and partnerships among government, industry, and universities. The case studies discussed below illustrate how regions combine these tools. The initiatives underway in New York, Colorado, Illinois, and Montana represent different approaches to combining these tools, often alongside federal programs and funding. These regions were selected because each has a significant quantum-focused initiative with a photonics component and is frequently identified by quantum stakeholders as an important center of activity at the intersection of quantum technology and photonics.

Although these initiatives share similar goals, they differ in emphasis and implementation. New York's efforts center on NY Creates and AIM Photonics; Colorado's on the Elevate Quantum Tech Hub and Quantum Commons; Illinois' on the Illinois Quantum and Microelectronics Park (IQMP); and Montana's on the Headwaters Tech Hub and its PhotonIQ initiative. Together, they illustrate different approaches to building regional capabilities for quantum and photonics manufacturing. Because many of these initiatives are new or still under development, their effectiveness in creating sustainable manufacturing and commercialization pathways has not yet been demonstrated.

New York: Shared Photonics and Semiconductor Manufacturing Infrastructure

New York's approach builds on a long-standing semiconductor and photonics ecosystem, with NY Creates' Albany NanoTech Complex and AIM Photonics serving as key components of the state's shared manufacturing infrastructure. Although AIM Photonics was established with significant federal support, it operates within a broader ecosystem supported by New York State, industry, universities, and other partners. Backed by substantial state investment, AIM Photonics provides end-to-end capabilities spanning design, fabrication, assembly, packaging, testing, and commercialization support for integrated photonic devices.[62] Together, these facilities offer advanced manufacturing infrastructure and transition capabilities that help bridge the gap between university research and industrial production and lower barriers for companies seeking to develop and scale PIC technologies.

New York's approach also extends beyond physical infrastructure to workforce development. Photonics and semiconductor-oriented programs such as NY Creates and AIM Photonics are developing training

[62] AIM Photonics, "TAP: America's First Accessible 300 mm Photonic Packaging Facility," accessed June 2026, https://www.aimphotonics.com/top-10-tap.

opportunities tied to foundries, packaging infrastructure, and advanced manufacturing.[63] These efforts build on the significant overlap between semiconductor, photonics, and quantum manufacturing skill requirements. Overall, New York represents an infrastructure-led model built around shared semiconductor and photonics manufacturing capabilities.

Colorado: Commercialization and Quantum Ecosystem Development

Colorado's regional strategy is led by the Elevate Quantum Tech Hub, which coordinates a broader ecosystem of companies, academic, and research institutions, and government agencies across Colorado and the Mountain West. A central component of this effort is the Quantum Commons, a regional hub designed to support quantum technology development, commercialization, and ecosystem growth.[64] The Quantum Commons is expanding access to specialized quantum infrastructure, including cryogenic testing capabilities, advanced control electronics, and shared laboratory space for technology development and commercialization.[65]

Colorado has paired this infrastructure with programs focused on commercialization and company development. A particularly relevant component for PIC manufacturing is QPICs, a fast-turn photonic fabrication capability being developed within the Colorado ecosystem. QPICs seeks to address long fabrication and iteration cycles by providing quantum technology developers with access to rapid-turn, low-volume fabrication and support for quantum-relevant materials and processes.[66] It is designed to bridge research-scale fabrication and larger commercial foundries, providing a more flexible environment for device and process development before technologies transition to higher-volume manufacturing.

Other initiatives provide broader commercial support. The Quantum Commons campus and Commercialization Lab provide companies with access to development, testing, and equipment. Programs such as Q-PAC, a commercial-grade quantum open architecture system, are designed to accelerate technology adoption, workforce development, and collaboration among industry, academic, and government stakeholders. [67]

State incentives form another part of the strategy. In 2024, the state enacted HB24-1325, creating $74 million in refundable tax credits to support the growth of Colorado's quantum industry, unlock federal funding opportunities, and generate additional economic activity. Because the credits are refundable, startups with little or no state tax liability can still benefit. These incentives were developed in conjunction with Elevate Quantum, which subsequently became the only quantum-focused hub to receive implementation funding through the federal Tech Hubs program.[68] Colorado therefore

[63] "Workshops and Boot Camps," AIM Photonics, accessed June 2026, https://www.aimphotonics.com/workshops-and-boot-camps; Larry Rulison, "NY Creates, Micron Start Workforce Training Program for Chip Workers," *Times Union*, May 4, 2026, https://www.timesunion.com/business/article/ny-creates-micron-start-workforce-training-22232638.php.
[64] Colorado Governor's Office, "Quantum Is Best in the West: Governor Polis Celebrates the Grand Opening of Colorado's Quantum Commons, Continuing Colorado's National Quantum Leadership," August 28, 2025, https://governorsoffice.colorado.gov/governor/news/quantum-best-west-governor-polis-celebrates-grand-opening-colorados-quantum-commons-continuing.
[65] Elevate Quantum, "Elevate Quantum Launches Cryogenic Testing Lab to Accelerate Quantum Hardware and Software Commercialization," November 26, 2025, https://www.elevatequantum.org/news/elevate-quantum-launches-cryogenic-testing-lab-to-accelerate-quantum-hardware-and-software-commercialization.
[66] "QPICs," QPICs, accessed August 12, 2026, https://www.qpics.com/.
[67] Elevate Quantum, "Elevate Quantum and Partners Launch the Nation's First Quantum Open Architecture System in Colorado," November 14, 2025, https://www.elevatequantum.org/news/elevate-quantum-and-partners-launch-the-nations-first-quantum-open-architecture-system-in-colorado.
[68] Colorado Governor's Office, "Quantum Is Best in the West."

represents a model centered on commercialization and quantum ecosystem development, combining specialized shared infrastructure, commercialization programs, workforce activities, regional coordination, and state incentives.

Illinois: A Co-Located Quantum and Microelectronics Ecosystem

Illinois' strategy centers on the Illinois Quantum and Microelectronics Park (IQMP), a large-scale effort to build a concentrated quantum and microelectronics ecosystem in the Chicago region. The initiative combines physical infrastructure development with supplier attraction and commercialization activities. In addition to providing space for quantum system developers, IQMP seeks to co-locate component suppliers, testing capabilities, cryogenic infrastructure, and other supporting resources needed to accelerate technology development and deployment.

The physical clustering strategy is complemented by state and local incentives intended to attract companies and manufacturing investment. In 2024, Illinois implemented a series of tax policy changes intended to support emerging technology industries, including quantum technologies. One of the most significant changes was the creation of Quantum Economic Zones. These zones provide qualifying companies with exemptions on certain utility taxes and sales taxes on building materials used for facility construction and expansion.[69] IQMP is one such zone; it is under development and has already attracted several tenants.[70]

Cook County has supplemented Illinois' broader quantum and microelectronics incentives through the Class 8 MICRO property tax incentive program. Established to encourage manufacturing, research, and development of semiconductors, microchips, quantum computers, and associated component technologies, the program provides qualifying projects with a reduced property tax assessment level of 10%, significantly lowering the taxable assessed value of eligible property for a period of 30 years.[71] Illinois therefore represents a co-location and cluster-development model, using a physical quantum and microelectronics park, supplier attraction, shared supporting infrastructure, and state and local incentives to build a concentrated regional ecosystem.

Montana: A Network and Services-Based Model

Montana's approach centers on the Headwaters Tech Hub, a regional initiative that focuses less on large physical infrastructure investments. Although federally supported, Headwaters brings together regional industry, academic, and other partners and is included here because of its role in shaping Montana's broader photonics ecosystem. Through its PhotonIQ initiative, Headwaters is developing engineering support services, testing capabilities, and partner networks intended to help companies navigate challenges associated with PIC design, prototyping, wafer testing, packaging, and commercialization. Rather than focusing solely on physical infrastructure, the initiative seeks to reduce barriers to accessing expertise, specialized capabilities, and manufacturing partners. Montana therefore represents a more networked, services-oriented model that connects companies to capabilities rather than attempting to replicate the full manufacturing value chain locally.

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[69] "Quantum Enterprise Zone Program," Illinois Department of Commerce and Economic Opportunity, accessed June 2026, https://dceo.illinois.gov/expandrelocate/incentives/quantum-enterprise-zone-program.html; "DCEO Incentives," Innovate Illinois, accessed June 2026, https://innovate-illinois.com/dceo-incentives/.

[70] "About," Illinois Quantum and Microelectronics Park, accessed June 2026, https://iqmp.org/about/.

[71] Cook County Assessor's Office, *Class 8 MICRO Eligibility Bulletin*, accessed June 2026, https://prodassets.cookcountyassessoril.gov/s3fs-public/2025-02/Class8MICROEligibilityBulletin.pdf?VersionId=gM6sINWAdbFTMZRpToP4NnbGXusj8Pxg.

Other Regional Initiatives

The four case studies illustrate distinct regional models, but they do not capture the full range of activity underway across the country. Other regional ecosystems similarly combine state, federal, academic, and private-sector resources to strengthen manufacturing and commercialization capabilities. Indiana and the broader Midwest region are advancing infrastructure investments through the Silicon Crossroads Microelectronics Commons Hub. Led by the Applied Research Institute and supported by federal and regional governments, academic institutions, and industry partners, the initiative seeks to accelerate the transition of advanced microelectronics technologies from research and development environments into domestic prototyping and manufacturing. Through pilot-line development and shared infrastructure, the hub aims to provide pathways for moving promising quantum and photonic technologies toward production and strengthen domestic manufacturing capabilities.

Ohio has invested in a range of quantum workforce initiatives, including The Ohio State University's Center for Quantum Information Science and Engineering and a $7 million state investment in the Ohio Institute for Quantum Computing Research, Talent, and Commercialization at Miami University.[72] These programs support specialized degree offerings, hands-on training, connections with industry, and commercialization activities.

Many existing workforce programs, however, remain focused on research and engineering rather than on the manufacturing skills needed to support fabrication, packaging, testing, and scale-up. Interviews conducted for this assessment suggest that workforce needs may increasingly shift toward technicians, process engineers, packaging specialists, test engineers, and other personnel directly involved in manufacturing and system-integration activities. QED-C workforce research supports this finding and has identified a growing need for technical personnel as quantum technologies move from research and prototyping toward commercialization and manufacturing.[73]

Comparing Regional Approaches

The case studies show that regional initiatives are pursuing competing approaches rather than converging on a common model. Some emphasize physical manufacturing infrastructure, whereas others focus on commercialization, co-location, or connecting companies to capabilities elsewhere (see Table 3 for a high-level comparison of approaches). Regional hubs often act as ecosystem integrators, linking resources that span multiple institutions and funding sources.

Table 3: Comparison of Various Regional Approaches

Region	Primary Model	Key Components	PIC Manufacturing Relevance
New York	Shared manufacturing infrastructure	AIM Photonics, NY Creates, TAP facility	Fabrication, packaging, testing

[72] "Ohio Invests $7 Million in Miami University to Launch Statewide Quantum Computing Institute," *Ohio Tech News*, July 25, 2025, https://www.ohiotechnews.com/ohio-invests-miami-university-quantum-institute/; The Ohio State University College of Engineering, "Ohio State Establishes Center for Quantum Information Science and Engineering," April 25, 2022, https://engineering.osu.edu/news/2022/04/ohio-state-establishes-center-quantum-information-science-and-engineering.

[73] QED-C, *Guide to Building a Quantum Technician Workforce: Reskilling and Upskilling Recommendations to Prepare a Workforce of Quantum Technicians* (QED-C, October 2023), https://quantumconsortium.org/workforce23.

Region	Primary Model	Key Components	PIC Manufacturing Relevance
Colorado	Commercialization ecosystem	Elevate Quantum, Quantum Commons	Testing, commercialization
Illinois	Co-located cluster	IQMP, incentives	Company/supplier co-location
Montana	Networked services	Headwaters, PhotonIQ	Design, testing, manufacturing navigation

Coordination, Specialization, and Duplication Across Regional Initiatives

As state and regional investments in quantum and photonics technologies continue to expand, stakeholders have questioned whether these initiatives are developing complementary capabilities or unnecessarily duplicating one another. Interviews conducted for this assessment suggest that the evidence is mixed: regional initiatives exhibit elements of both collaboration and competition.

Areas of Complementarity

The case studies suggest that regional initiatives are developing complementary strengths across the quantum-relevant PIC manufacturing pathway. New York has emphasized shared fabrication, packaging, and test infrastructure; Colorado has focused on rapid-turn fabrication, testing, and commercialization support; Illinois is developing a co-located quantum and microelectronics ecosystem with shared enabling infrastructure; and Montana is emphasizing engineering support, testing, and connections to external manufacturing partners.

Because no single region currently provides every capability needed to move quantum-relevant PICs from research to commercial production, these differences can be useful if companies can move easily between regional resources. A company may, for example, prototype or test a device in one region, rely on packaging or integration capabilities in another, and ultimately transition the process to a commercial foundry elsewhere.

Interviews suggest that such coordination already occurs through research partnerships, industry networks, regional hubs, and individual technology-development projects. The value of regional specialization therefore depends less on each region building a complete manufacturing ecosystem and more on whether specialized capabilities can be connected into a usable national pathway.

Potential Duplication or Fragmentation

At the same time, some regional initiatives are developing similar capabilities, particularly in areas such as PIC design support, prototyping, testing, workforce development, and commercialization services. Some overlap benefits companies by offering alternative providers and reducing dependence on a single facility or region.

A greater concern is whether the market can sustain multiple facilities offering similar services. Quantum-relevant PIC demand remains relatively small, and many regional capabilities have been

established with significant public support. If several facilities compete for the same limited user base, some may struggle to generate the recurring revenue needed to sustain operations as initial public funding declines.

Fragmentation presents a separate challenge. Even when capabilities are technically complementary, companies may have difficulty identifying which facility to use, understanding access requirements, or transferring designs and processes between organizations. Greater visibility of available capabilities, clearer referral pathways, and stronger relationships with commercial manufacturers could help reduce these barriers.

Remaining Gaps Not Clearly Addressed by Current Programs

Despite substantial investment across infrastructure, commercialization, workforce development, and ecosystem-building initiatives, several manufacturing challenges identified elsewhere in this assessment remain only partially addressed. Stakeholders consistently highlighted foundry access, process transfer, advanced testing capabilities, packaging, heterogeneous integration, and low-volume manufacturing as persistent gaps. These findings also align with recent QED-C survey results, which identified fabrication and prototyping, assembly and advanced packaging, process development and scale-up support, and testing and characterization among the infrastructure needs most frequently reported as inadequately met.[74] Multiple interviewees emphasized that testing infrastructure, particularly wafer-scale characterization, cryogenic testing, and other specialized validation capabilities, is emerging as a critical bottleneck as technologies move beyond laboratory-scale demonstrations.

Many existing regional initiatives focus on technology development and commercialization, but fewer explicitly address the operational challenges associated with scaling production. As a result, companies still struggle to transition from prototype-scale development to sustainable commercial manufacturing, even in regions with robust innovation ecosystems. A second limitation is the maturity of regional initiatives. Many of the largest programs described above are new, still being implemented, or expanding capabilities that have not yet operated long enough for their effects on commercial quantum manufacturing to be fully assessed. The current landscape therefore demonstrates substantial experimentation and investment in regional ecosystem development, but has not yet shown which models will prove most effective over the long term.

Viewed together, the case studies suggest that the national challenge is not simply whether individual regions possess the “right” programs but whether specialized regional capabilities can be connected into reliable pathways that allow companies to move from research and prototyping through testing, packaging, pilot manufacturing, and ultimately commercial production.

Recommendations

This report addresses the challenges associated with moving the fabrication of PICs for quantum-relevant applications from research and prototyping to commercial manufacturing. A gap remains between research-scale fabrication of PICs and mature commercial foundry production. University and national laboratory facilities can support customized devices and rapid experimentation but cannot produce at commercial scale. Existing photonics manufacturing capacity serves mature non-quantum applications and is geared toward specific materials and associated wavelength ranges. It does not solve

[74] QED-C, *Federally Funded Quantum Infrastructure Assessment: Recommendations for Federal Coordination and Investment* (QED-C, forthcoming).

the current scale-up challenge for quantum-relevant PICs or satisfy the need for quantum materials processing, lower loss, heterogeneous integration, cryogenic compatibility, specialized packaging, and quantum-specific testing.

New capacity must match the stage of demand and be able to expand as designs mature. It must support prototype validation and pilot production today and allow technologies to transition to larger commercial foundry runs as market demand grows. Current demand is uncertain, and many quantum-relevant fabrication requirements are not yet met through accessible commercial channels. That combination can slow both the maturation of quantum-relevant PIC designs and the emergence of repeatable production pathways.

Taken together, these findings suggest the near-term challenge is not simply a lack of fabrication capacity. The priority is to strengthen the capabilities and pathways needed to move quantum-relevant PICs from research and early prototyping toward repeatable commercial manufacturing and allow capacity to expand as demand develops. The following recommendations identify actions for government, industry, research institutions, regional organizations, and the broader quantum and photonics community in areas including supply-chain visibility, heterogeneous integration, fast-turn fabrication and packaging, manufacturing readiness, and pathways from research to commercial production.

Recommendation 1: Include photonics fabrication in quantum supply-chain analysis

The Under Secretary of Commerce for Standards and Technology should ensure that federal quantum supply-chain analysis explicitly considers integrated photonics materials and all aspects of PIC fabrication. The analysis should map dependencies and bottlenecks across the tools and materials that matter for photonic devices, including materials relevant for quantum devices. Industry associations, foundries, materials and equipment suppliers, and the broader quantum and photonics community should support this analysis by sharing information on critical dependencies, alternative suppliers, and emerging material and equipment needs. Industry-led efforts can also help maintain visibility into supply-chain changes as technologies and commercial requirements evolve. This assessment should consider the capabilities of U.S. allies and partners to meet U.S. needs as it evaluates supply chain security. Many of these dependencies overlap with the much larger AI and data-center photonics buildout, presenting an opportunity to fold quantum considerations into broader industrial-base assessment. One important venue for this analysis is the supply-chain and manufacturing-barriers plan required by Executive Order 14413, which should consider integrated photonics fabrication as an enabling technology for quantum computing.

Recommendation 2: Sustain and expand heterogeneous integration research and development, including process transfer and manufacturing readiness

Heterogeneous integration is a central technical bottleneck for quantum photonics. Federal research funding for this work across materials, integration approaches, and fabrication methods, covering both quantum-specific and general advances, should be sustained. Within that portfolio, investments should take process transfer and manufacturing readiness into consideration. The research and manufacturing communities also play an important role in moving advances beyond the laboratory. Universities, national laboratories, foundries, equipment and materials suppliers, and quantum technology developers should involve manufacturing partners earlier in development to ensure processes can be transferred, qualified, and reproduced in commercial manufacturing environments. Potential funders include the Defense Advanced Research Projects Agency (DARPA), Air Force Research Laboratory (AFRL), National Science Foundation (NSF), and National Institute of Standards and Technology (NIST), with the

size and direction of investments tailored to the envisioned end-user requirements. The Executive Order 14413 manufacturing-science and manufacturing-barriers provisions reinforce this recommendation.

Recommendation 3: Expand or establish a rapid-cycle, quantum-first fabrication and packaging capability

The most useful near-term investment is an appropriately sized quantum-first capability built for rapid iteration, low-volume custom work, and services for commercial customers.[75] This capability need not be greenfield or confined to one location. It could take the form of an expanded or refitted facility, a dedicated capability within a broader foundry, or a coordinated network of complementary facilities. It should serve quantum companies and researchers with short cycle times rather than the slower cadence of shared MPW runs at large foundries. Total quantum demand is small. The priority should be to mature fast-turn, custom quantum-relevant PIC fabrication into a sustainable commercial-facing capability rather than maximizing production volume. Where possible, investments should build on and connect existing capabilities rather than create duplicative facilities. Commercial manufacturers should be engaged early to ensure that successful processes have a pathway to larger-scale production.

Service offerings of this kind are beginning to emerge, including within federally supported regional hubs such as Elevate Quantum and Headwaters. To help ensure commercial viability, these facilities should use quantum as the anchor market and also serve other markets, including telecommunications, sensing, and defense.

Recommendation 4: Support manufacturing readiness and strengthen lab-to-fab process-transfer pathways for quantum-relevant PICs

Public and private investment should support the transition from successful prototypes to repeatable manufacturing, including process qualification, process transfer, pilot production, and other activities needed to prepare technologies for commercial fabrication. Foundries, pilot facilities, universities, national laboratories, and quantum technology developers should engage manufacturing partners earlier in development and establish clearer practices for transferring processes between facilities. These practices should address process documentation, tool compatibility, design constraints, qualification requirements, and other information needed to reproduce a process in a commercial manufacturing environment. Funding should be sized to the requirements of manufacturing scale-up and should prioritize projects with credible pathways to commercial production rather than technology development alone.

Recommendation 5: Structure investment in shared photonics-fabrication infrastructure for broad access and multiuse value

Although quantum-first capabilities are preferable for technologies that require rapid iteration, process development, or specialized materials, not all quantum-relevant PICs will require this level of flexibility. As technologies mature and processes stabilize, some quantum companies may be able to transition to established commercial photonics processes and larger commercial fabrication facilities. Access to these facilities can provide quantum companies with a pathway to commercial-grade manufacturing without requiring dedicated quantum capacity.

Investments in photonic fabrication should be structured to ensure broad access, multiuse value, and a credible path toward sustained utilization. Facility operators and commercial partners should pursue

[75] Existing programs, like QPICs, provide a partial model but vary in process flexibility and access to end-to-end heterogenous integration, packaging, and test capability.

business models that combine quantum users with larger markets where appropriate, including telecommunications, data centers, sensing, and defense. Potential approaches include fee-for-service access, commercial partnerships, anchor users, and other models that increase utilization and preserve access for emerging quantum companies.

Federal investments can reinforce these objectives. Where the federal government is already making substantial investments in large commercial foundries, those investments should, where appropriate, help ensure quantum companies and researchers can access relevant photonic fabrication capabilities rather than primarily benefiting individual companies or established high-volume markets. For example, the Department of Commerce should condition a portion of the CHIPS for America quantum foundry investments on assured access for quantum companies, startups, and researchers. For quantum technologies that have progressed beyond the rapid process-development stage and can use established foundry processes, shared MPW runs can provide a cost-effective pathway to commercial-grade fabrication. Federal investments could therefore support assured access to relevant photonic processes, including through photonic MPW capacity, appropriate MPW-run cadences, and investment in improved photonic process design kits.

The same principles should apply to future investments, which could include quantum-specific capabilities added at existing high-volume fabs or a larger heterogeneous-integration manufacturing facility. As technologies mature and production requirements increase, these multi-use commercial facilities can provide a pathway from the fast-turn and pilot-scale capabilities described in recommendation 3 toward repeatable production at greater scale.

Measures ranging from subsidized foundry access to advance market commitments should be appropriately sized and include performance-based incentives to ensure they deliver value to both taxpayers and the broader quantum industry. Measures of success could include reductions in cost and lead time, the number of users and fabrication runs supported, process utilization, private-sector co-investment, successful product transitions, and the extent to which continued subsidies become unnecessary. In fulfilling of the Executive Order 14413 directive to develop a plan for demand-side instruments for quantum-enabling components by October 20, 2026, the Department of War, Department of Energy, Department of Commerce, and National Science Foundation should consider these criteria.

Recommendation 6: Strengthen regional manufacturing transition networks and specializations

Regional hubs, industry organizations, universities, foundries, and quantum companies should work together to create clearer pathways between design, prototyping, fabrication, packaging, testing, and commercial manufacturing resources. These pathways should help companies identify appropriate providers, understand available capabilities and access requirements, and transition designs and processes from one facility or stage of production to the next. Rather than attempting to re-create the full manufacturing value chain within every region, regional initiatives should identify areas of specialization, establish relationships with complementary facilities elsewhere, and provide companies with clear pathways to move between them. Regional hubs, manufacturers, universities, and community colleges should also coordinate and share information on workforce programs around common manufacturing needs, including technicians, process engineers, packaging specialists, and test engineers, and, where possible, build on existing semiconductor and photonics training rather than creating entirely separate quantum workforce pipelines.

Federal and state programs should support these efforts by using funding criteria that emphasize collaboration, successful company transitions, commercial manufacturing outcomes, and sustainable industry engagement rather than infrastructure creation alone. The U.S. Economic Development Administration and other regional-development programs could support shared directories of capabilities and access requirements, cross-regional referral networks, and partnerships connecting universities and prototyping facilities with packaging, testing, pilot-production, and commercial manufacturing providers.

Conclusion

The quantum industry's evolution and ultimate demand for quantum-relevant PICs are difficult to predict. Therefore, building capacity ahead of demand is not advisable. Any near-term public or private investment should prioritize broadly accessible fabrication, packaging, testing, and transition capabilities with clear, built-in pathways to scale. Building these pathways will require coordinated action across government, industry, research institutions, regional organizations, and private investors, with each playing a different role as technologies move from research toward sustainable commercial manufacturing.

Appendix 1: Workshop Agenda

QED-C convened a workshop on commercial fabrication of photonic integrated circuits for quantum technologies on July 30, 2026, at the Denver Athletic Club.

Time	Session
8:30 – 9:00 AM	Registration and Networking Breakfast
9:00 – 9:15 AM	**Welcome**
9:15 – 9:45 AM	**Assessment Overview** Preliminary findings from the QED-C Commercial PIC Fabrication Assessment
9:45 – 10:45 AM	**Panel Discussion: The Current State of Commercial PIC Fabrication** Perspectives from commercial foundries and industry on the current manufacturing landscape, capabilities, and challenges **Moderator:** John Burke – Beacon Photonic ○ **Shantanu Misra** – GlobalFoundries ○ **Robert Visser** – Applied Materials ○ **Brian Wilbur** – SkyWater Technology ○ **Vimal Kamineni** – PsiQuantum
10:45 – 11:00 AM	Break
11:00 AM – 12:00 PM	**Panel Discussion: Ecosystem Building Initiatives** Discussion of infrastructure investments, commercialization support, workforce development, and regional ecosystem development **Moderator:** Constanza Vidal Bustamante – CNAS ○ **Philip Makotyn** – IQMP ○ **Jessi Olsen** – Elevate Quantum ○ **Christopher Striemer** – AIM Photonics TAP Facility ○ **Ben Losby** – QCORE
12:00 – 1:00 PM	Lunch
1:00 – 1:45 PM	**Breakout Session 1: Transitioning from Research to Commercial Manufacturing**
1:45 – 2:00 PM	Breakout Report Out
2:00 – 2:15 PM	Break
2:15 – 3:00 PM	**Breakout Session 2: Manufacturing Bottlenecks and Capability Gaps**
3:00 – 3:15 PM	Breakout Report Out
3:15 – 3:30 PM	Break
3:30 – 4:15 PM	**Breakout Session 3: Prioritizing Investments and Policy Recommendations**
4:15 – 4:30 PM	Breakout Report Out
4:30 – 4:50 PM	**Workshop Synthesis and Discussion** Key themes, areas of consensus, and remaining questions
4:50 – 5:00 PM	Closing Remarks and Next Steps
5:00 – 6:00 PM	Reception • 3rd Floor Foyer, Denver Athletic Club

Appendix 2: Workshop Participant List

Jessica Avery, SRI International
Marcus Bagnell, SRI International
Jordan Bass, SRI International
Jennifer Black, Vescent Technologies
John Burke, Beacon Photonics
Zijun Chen, Lawrence Livermore National Laboratory
Patrick Chu, Sandia National Laboratories
Bryan DeBono, Quantinuum
Peter DeVore, Lawrence Livermore National Laboratory
Jonathan Felbinger, QED-C
Amirhossein Ghods, Mesa Quantum
Adam Heiniger, TOPTICA Photonics
Stephen Heinrich-Barna, Anametric, Inc.
Paul Juodawlkis, MIT Lincoln Laboratory
Vimal Kamineni, PsiQuantum
Christopher Kocot, Coherent Corp
Keisuke Kojima, Boston Quantum Photonics
Ben Losby, QCORE-Montana State University
Philip Makotyn, IQMP
Shantanu Misra, GlobalFoundries
Jessi Olsen, Elevate Quantum
Elliott Ortmann, Xanadu Quantum Technologies
Wil Oxford, Anametric, Inc.
Scott Papp, NIST
Saeed Pegahan, Modulight USA
Joanna Peters, StratConGlobal Inc.
Amirhassan Shams-Ansari, Monarch Quantum
Mark Stone, Atom Computing
Christopher Striemer, AIM Photonics TAP Facility
Brandon van Hoff, SRI International
Constanza Vidal Bustamante, Center for a New American Security
Robert Visser, Applied Materials
Brian Wilbur, SkyWater Technology
Chris Wood, QPICs
Annie Wyhof, SRI International

Appendix 3: Semiconductor and PIC Fabrication Comparison

The table below compares the characteristics of semiconductor and integrated photonics fabrication. This comparison highlights how PIC fabrication requirements are less stringent in some ways, but less standardized in others.

Dimension	Conventional Semiconductor	Photonic Integrated Circuits
Where cost concentrates	Front-end wafer fab: lithography (~$400M per extreme ultraviolet tool), masks, R&D, amortized over very high volumes.[a]	Back-end packaging, assembly, and test: 70%–80% of total chip cost (vs. ~20% for electronic ICs), driven by fiber alignment and hermetic sealing.[b]
Design ecosystem & standardization	Mature IP libraries are widely available and standardized across foundries; mature electronic design automation (EDA) tools.	Emerging and fragmented: separate process design kits (PDKs) per foundry; EDA tools less mature.[c]
Equipment (tools)	Tools for lithography, deposition, etch, planarization, metrology; extreme ultraviolet (EUV) lithography at the leading edge.	Same core tool families, but deep ultraviolet (DUV) lithography on trailing-edge nodes (mostly 130–250 nm), plus specialty steps (wafer bonding, micro-transfer printing) for heterogeneous integration.[d]
Facilities (plant)	Class-1 cleanroom microfabrication, typically 300 mm wafer.	Also cleanroom microfabrication (mostly 200 mm). Si, InP, SiN, and TFLN typically run in separate fabs.[e] Compound semiconductor lines physically isolated from silicon lines to avoid Ga/In contamination.[f]
Materials & integration	Predominantly silicon with dopants and standard interconnect metals.	Heterogeneous integration required; no single material provides all required functions.[g]
Type of precision required	Atomic-scale dimensional control plus material purity (dopants, contaminants, isotopes) at parts-per-billion levels.	Qubit-dependent. For photonic computing, geometric and optical-interface precision. Loss-driven, not purity-driven.
Critical feature size	2–3 nm at the leading edge with sub-nm dimensional control.[h]	Sub-µm to several µm, scaled to optical wavelength: typical single-mode SOI waveguides are 450–500 nm wide × 220 nm high at 1,550 nm, 100–1,000 times larger than leading-edge logic.[i] Emerging techniques (inverse design) have < 50 nm critical feature size.

Note: R&D = research and development; IC = integrated circuit; IP = intellectual property; Si = silicon; InP = indium phosphide; SiN = silicon nitride; TFLN = thin-film lithium niobate; Ga = gallium; In = indium; SOI = silicon-on-insulator. Units: mm = millimeter; µm = micrometer; nm = nanometer.

[a] Katie Tarasov, "Exclusive Look at the Creation of High NA, ASML's New $400 Million Chipmaking Colossus," *CNBC*, May 22, 2025, https://www.cnbc.com/2025/05/22/exclusive-look-at-high-na-asmls-new-400-million-chipmaking-colossus.html.

[b] Drew Weninger *et al*., "Advances in Waveguide to Waveguide Couplers for 3D Integrated Photonic Packaging," *Light: Science & Applications* 15 (2026): 17, https://doi.org/10.1038/s41377-025-02048-w; QED-C, *Environmental and Vacuum Packaging for Quantum Sensors* (SRI International, November 2022), https://quantumconsortium.org/publication/environmental-and-vacuum-packaging-for-quantum-sensors/.

[c] "Wave Photonics Streamlines PIC Design with PDK Management Platform," *Photonic Integrated Circuits*, August 13, 2025, https://picmagazine.net/article/122290/Wave_Photonics_streamlines_PIC_design_with_PDK_management_platform; "Methods and Apparatus for Automated Design of Semiconductor Photonic Devices," U.S. Patent No. 10,503,865, https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/10503865.

[d] Xuetong Zhou *et al*., "Silicon Photonics for High-Speed Communications and Photonic Signal Processing," *npj Nanophotonics* 1 (2024): 27, https://www.nature.com/articles/s44310-024-00024-7; Ken Giewont *et al*., "300-mm Monolithic Silicon Photonics Foundry Technology," *IEEE Journal of Selected Topics in Quantum Electronics* 25, no. 5 (2019): 8200611, https://doi.org/10.1109/JSTQE.2019.2908790.

[e] Yi Wang *et al*., "Scaling Photonic Integrated Circuits with InP Technology: A Perspective," *APL Photonics* 9, no. 5 (2024): 050902, https://doi.org/10.1063/5.0200861; Di Zhu *et al*., "Integrated Photonics on Thin-Film Lithium Niobate," *Advances in Optics and Photonics* 13, no. 2 (2021): 242–352, https://doi.org/10.1364/AOP.411024.

[f] Marie Christine Roure *et al*., "Cross-Contamination Risk Evaluation During Fabrication of III-V Devices in a Silicon Processing Environment," *Solid State Phenomena* 219 (2014): 63–7. https://doi.org/10.4028/www.scientific.net/ssp.219.63.

[g] Paramjeet Kaur *et al*., "Hybrid and Heterogeneous Photonic Integration," *APL Photonics* 6, no. 6 (2021): 061102, https://doi.org/10.1063/5.0052700.

[h] "TSMC Officially Begins 2nm Chip Volume Production in Q4 2025," *Taipei Times*, December 31, 2025, https://www.taipeitimes.com/News/biz/archives/2025/12/31/2003849772.

[i] Qidi Liu *et al*., "Progress in Passive Silicon Photonic Devices: A Review," *Photonics* 12, no. 9 (2025): 928, https://doi.org/10.3390/photonics12090928.

Appendix 4: Quantum-Relevant PIC Fabrication Requirements

This appendix explores common photonic integrated circuit (PIC) platforms and modality-specific quantum-relevant PIC requirements in greater detail.

Integrated photonics has no single dominant material platform. A primary fabrication constraint is the need to combine specialized materials and components into one package that performs all needed functions. For quantum applications, the challenge is greater because lost or scattered photons can destroy quantum information. Each added material interface can increase loss, and loss can limit quantum-relevant PICs scalability.

Silicon-on-insulator (SOI) and silicon nitride (SiN) are the most commercially mature PIC materials. Both were developed mainly for telecommunications applications. SOI supports dense routing and on-chip signal processing near 1,550 nm, where optical fiber loss is lowest.[76] SiN offers low propagation loss across a wider range of wavelengths, making it useful for quantum systems that need visible or near-visible light.[77] These platforms matter because they have existing foundry production pathways, even if they do not meet every quantum need.

Light generation creates another constraint. Silicon and SiN do not emit light efficiently, so lasers and deterministic single-photon emitters usually rely on III-V materials such as indium phosphide (InP) or gallium arsenide (GaAs). Integrating these sources with silicon-based routing remains an active development area.[78] Quantum companies such as Beacon Photonics are exploring doping SiN to make it emit light more efficiently.[79] Photonic qubit systems can also generate photons through nonlinear processes in the routing material.[80]

Thin-film lithium niobate (TFLN) is an important emerging material because it supports efficient electro-optic modulation, wavelength conversion, and entangled photon-pair generation.[81] Those functions are difficult or impossible in silicon. TFLN also maintains its electro-optic performance at cryogenic temperatures, which makes it relevant to superconducting and spin qubit systems.[82]

Active control components, including modulators, phase shifters, and switches, route and reconfigure light. Thermo-optic tuning is simple but can be slow, power hungry, and poorly suited to cryogenic systems.[83] Faster electro-optic switching is possible in materials such as TFLN or III-V semiconductors, but those materials are harder to integrate with silicon routing layers.[84] This matters because some quantum architectures need fast, low-loss switching to scale.

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[76] Ashutosh Singh *et al.*, *Photonic Quantum Information with Time-Bins: Principles and Applications*, arXiv, July 10, 2025, https://doi.org/10.48550/arXiv.2507.08102.
[77] Pascual Muñoz *et al.*, "Silicon Nitride Photonic Integration Platforms for Visible, Near-Infrared and Mid-Infrared Applications," *Sensors (Basel)* 17, no. 9 (2017): 2088, https://pmc.ncbi.nlm.nih.gov/articles/PMC5620990/.
[78] Chen Shang *et al.*, "Perspectives on Advances in Quantum Dot Lasers and Integration with Si Photonic Integrated Circuits," *ACS Photonics* 8, no. 9 (2021): 2555–66, https://pubs.acs.org/doi/10.1021/acsphotonics.1c00707.
[79] John Rönn *et al.*, "Ultra-High On-Chip Optical Gain in Erbium-Based Hybrid Slot Waveguides," *Nature Communications* 10 (2019): 432, https://doi.org/10.1038/s41467-019-08369-w.
[80] Nicolas Maring *et al.*, "A Versatile Single-Photon-Based Quantum Computing Platform," *Nature Photonics* 18 (2024): 603–9, https://doi.org/10.1038/s41566-024-01403-4.
[81] Changhyun Kim *et al.*, "Integrated Lithium Niobate Photonic Devices for Photonic Quantum Information Science," *Nano Convergence* 12 no. 1 (2025): 65, https://doi.org/10.1186/s40580-025-00530-0.
[82] Jeffrey Holzgrafe *et al.*, "Cavity Electro-Optics in Thin-Film Lithium Niobate for Efficient Microwave-to-Optical Transduction," *Optica* 7, no. 12 (2020): 1714–20, https://doi.org/10.1364/OPTICA.397513.
[83] Muñoz *et al.*, "Silicon Nitride Photonic Integration Platforms."
[84] Kim, *et al.*, "Integrated Lithium Niobate Photonic Devices."

Superconducting nanowire single-photon detectors (SNSPDs) can detect single photons with high efficiency and low timing jitter.[85] They are increasingly integrated into PICs, but they operate at cryogenic temperatures. Cryogenic operations add material, thermal, and process constraints that standard photonics foundries do not always support.

Packaging brings material compatibility and process integration challenges together. Bonding or transfer-printing III-V devices onto silicon requires precise alignment and surface preparation.[86] Depositing TFLN on silicon requires managing thermal and crystal structure differences.[87] Fiber-to-chip coupling and dense optical and electrical interconnects are frequent sources of loss and cost. Because detectors, transducers, and several emitters operate at cryogenic temperatures, quantum PICs must be designed for low-temperature operation.[88] Packaging is therefore often a scaling bottleneck.

Modality-Specific Fabrication Challenges

For photonic quantum computing, the main fabrication challenge is integrating photon generation, low-loss routing, modulation, and detection in one process.[89] Photonic qubit systems use telecommunications wavelengths and materials because fiber loss is low, SNSPD detection efficiency is high, and telecom-band photonic components are mature.[90]

Color centers, by contrast, require the most heterogeneous material stack of any modality, with different materials needed for emission, routing, frequency conversion, tuning, and superconducting detection.[91] Cost-effective material integration is essential for scaling. One promising path is silicon T-centers, which emit at telecom wavelengths and could use mature complementary metal-oxide-semiconductor (CMOS) photonics infrastructure.[92]

For atomic qubit modalities such as trapped ions, neutral atoms, and color centers, wavelength requirements are set by physics; these systems operate at wavelengths determined by atomic structure. Color center systems often emit at shorter, visible wavelengths, but frequency conversion to the telecom band could allow them to use telecom-compatible routing and detection infrastructure.[93]

For trapped-ion systems, PICs route cooling, gate, and readout beams to ion trap zones.[94] As qubit counts grow, PICs can replace free-space optics that become impractical. Because photons do not carry quantum information, loss tolerances are less extreme than in photonic or color center systems. Operating wavelength is a primary fabrication challenge: ultraviolet wavelengths face photoinduced

[85] Ilya A. Stepanov *et al.*, *Superconducting Single-Photon Detectors for Integrated Quantum Photonics*, arXiv, May 14, 2026, https://doi.org/10.48550/arXiv.2605.14829.
[86] Shang *et al.*, "Perspectives on Advances in Quantum Dot Lasers."
[87] Fatemeh Karami *et al.*, "Integrated Quantum Photonics on Thin-Film Lithium Niobate," *Progress in Quantum Electronics* 106 (2026): 100614, https://doi.org/10.1016/j.pquantelec.2026.100614.
[88] Holzgrafe *et al.*, "Cavity Electro-Optics in Thin-Film Lithium Niobate."
[89] J. P. Sprengers *et al.*, "Waveguide Single-Photon Detectors for Integrated Quantum Photonic Circuits," *Applied Physics Letters* 99, no. 18 (2011): 181110, https://doi.org/10.1063/1.3657518.
[90] Kim *et al.*, "Integrated Lithium Niobate Photonic Devices."
[91] Kim *et al.*, "Integrated Lithium Niobate Photonic Devices."
[92] A. DeAbreu *et al.*, "Waveguide-Integrated Silicon T Centres," *Optics Express* 31, no. 9 (2023): 15045–57, https://doi.org/10.1364/OE.482008.
[93] Julia Maria Brevoord *et al.*, "Quantum Frequency Conversion of Single Photons from a Tin-Vacancy Center in Diamond," *Optica* 3, no. 6 (2025): 583–9, https://doi.org/10.1364/OPTICAQ.576448.
[94] Carmelo Mordini *et al.*, "Multizone Trapped-Ion Qubit Control in an Integrated Photonics QCCD Device," *Physical Review X* 15 (2025): 011040, https://doi.org/10.1103/PhysRevX.15.011040.

charging that degrades performance.[95] Trapped-ion PICs overlap with visible/ultraviolet photonics investment, so they may benefit from photonics work in biomedical, display, and augmented-reality applications. The table below summarizes how PICs are used in photonic, color-center, trapped-ion, neutral-atom, superconducting, and gate-defined spin qubit platforms, together with relevant material systems, operating wavelengths, and key integration challenges.

Modality	PIC Role	PIC Necessity	Material Platforms	Wavelength Band	Fabrication Requirements
Photonic	Photons are the qubits; the PIC is the processor.	Required, the computer is the PIC.	SiN/Si routing; III–V or FWM sources; TFLN electro-optics; SC detectors.	Telecom (~1,550 nm)	Ultra-low loss routing, fast switching, indistinguishable sources, and single-photon detectors.[a]
Color centers	Single photons link distant spins.	Enabling, optical interface for readout and networking.	Diamond, SiC; silicon T/G-centers; III–V quantum dots; SiN host; LN/AlN tuning and conversion.	Visible–NIR; telecom after conversion	Emitter positioning, tuning, telecom conversion, and cryogenic operation.
Trapped ion	Light-delivery — routes cooling, gate, and readout beams to ions; collects fluorescence.	Helpful, enabling at scale.	Alumina, AlN for UV; SiN for visible–NIR.	Visible and UV (~370–935 nm)	Visible/UV routing, low-loss couplers, high-extinction modulators, mitigation of UV-induced charging and heating.[b]
Neutral atom	Two roles: (1) control/readout, replacing bulk optics; (2) networking — nanophotonic cavity for atom–photon entanglement.	Helpful for control; enabling for networking.	(1) Visible–NIR waveguides in SiN/alumina/dielectric; (2) high-Q nanophotonic cavities, alumina membranes.	(1) Visible–NIR; UV emerging (2) visible–NIR at the atom, converted to telecom for fiber	Power handling, heat dissipation, visible/near-UV routing, precise resonance, small mode volume cavities, telecom conversion.[c]

[95] M. Ivory *et al.*, "Integrated Optical Addressing of a Trapped Ytterbium Ion," *Physical Review X* 11 (2021): 041033, https://doi.org/10.1103/PhysRevX.11.041033.

Modality	PIC Role	PIC Necessity	Material Platforms	Wavelength Band	Fabrication Requirements
Superconducting	Optical readout and microwave-to-optical transduction for networking. Not used for logic.	Helpful, enabling for optical networking at scale.	Lithium niobate; aluminum nitride; crystalline-silicon nanomechanics; SC detectors.	Microwave in, telecom out	Low-noise microwave-to-optical transduction at millikelvin temperatures.[d]
Gate-defined spin	None — qubits defined and controlled electrically.	Not in the logic path.	Si/SiGe, GaAs heterostructures; no PIC materials.	N/A (microwave/RF)	No current PIC requirement

Note: SiN = silicon nitride; III–V = group III–V compound semiconductors; FWM = four-wave mixing; TFLN = thin-film lithium niobate; SC = superconducting; SiC = silicon carbide; LN = lithium niobate; AlN = aluminum nitride; NIR = near-infrared; UV = ultraviolet; high-Q = high quality factor; Si = silicon; SiGe = silicon–germanium; GaAs = gallium arsenide; RF = radio frequency; and N/A = not applicable. T centers and G centers refer to optically active defect centers in silicon.

[a] Huihui Zhu *et al*., "Recent Progress Towards Large-Scale Integrated Photonic Quantum Computation," *npj Nanophotonics* 3 (2026): 20, https://www.nature.com/articles/s44310-026-00114-8; Vidur Raj *et al*., "Waveguide Integrated Superconducting Nanowire Single-Photon Detectors for Integrated Photonics," *Journal of Physics D: Applied Physics* 58, no. 24 (2025): 243001, https://doi.org/10.1088/1361-6463/add946.

[b] Gavin N. West *et al*., "Low-Loss Integrated Photonics for the Blue and Ultraviolet Regime," *APL Photonics* 4 (2019): 026101, https://doi.org/10.1063/1.5052502; M. Ivory *et al*., "Integrated Optical Addressing of a Trapped Ytterbium Ion," *Physical Review X* 11 (2021): 041033, https://doi.org/10.1103/PhysRevX.11.041033.

[c] Michael Gehl *et al*., "Characterization of Suspended Membrane Waveguides Towards a Photonic Atom Trap Integrated Platform," *Optics Express* 29, no. 9 (2021): 13129–40, https://doi.org/10.1364/OE.418986.

[d] Mohammad Mirhosseini *et al*., "Quantum Transduction of Optical Photons from a Superconducting Qubit," *Nature* 588 (2020): 599–603, https://doi.org/10.1038/s41586-020-3038-6.

Neutral atom systems are controlled by classical laser light. PICs serve multiple functions: delivering control light and supporting nanophotonic cavity integration for atom-photon entanglement.[96] This entanglement enables quantum networking and could help scale systems beyond a single chamber. Neutral-atom PIC fabrication therefore has separate requirements by function. Classical visible-wavelength light routing resembles trapped-ion requirements; precision nanophotonic cavity fabrication resembles color center requirements. Both are less mature than telecom photonics.

For superconducting systems, microwave-to-optical transducers could send qubit signals over optical fiber, reducing cryogenic wiring and enabling modular networking.[97] Transducers remain in the research stage because conversion efficiencies are too low and improving efficiency without adding noise remains difficult.[98] All components must operate at millikelvin temperatures within tight power budgets, limiting usable materials.

[96] Tamara Đorđević *et al.*, "Entanglement Transport and a Nanophotonic Interface for Atoms in Optical Tweezers," *Science* 373, no. 6562 (2021): 1511–14, https://doi.org/10.1126/science.abi9917.
[97] Akihiko Sekine *et al.*, "Microwave-to-Optical Quantum Transduction of Photons for Quantum Interconnects," *npj Nanophotonics* (2026), https://doi.org/10.1038/s44310-026-00130-8.
[98] Holzgrafe *et al.*, "Cavity Electro-Optics in Thin-Film Lithium Niobate."

Gate-defined spin qubits use electrical control and readout and do not depend on PICs for near-term scaling, but they could benefit from photonics for cryogenic links in the longer term.[99]

Some fabrication requirements overlap. For example, low-loss visible and near-ultraviolet waveguides are needed by both trapped-ion and neutral-atom systems. Neither platform demands quantum-level loss performance from these waveguides, meaning that advances driven by any modality, or by non-quantum applications that also require visible wavelengths, would benefit multiple modalities. Strong light-modulating materials are relevant to photonic quantum computing, color center frequency conversion, and superconducting transducers. Advances in etching quality, wafer-scale uniformity, and low-temperature device performance for any one of these applications would reduce barriers for the others.

[99] Guido Burkard *et al.*, "Semiconductor Spin Qubits," *Reviews of Modern Physics* 95 (2023): 025003, https://doi.org/10.1103/RevModPhys.95.025003.

Appendix 5: Notable Packaging and Foundry Facilities Updates Since 2023

This appendix updates the list within QED-C's 2023 report[100] with acquisitions, substantial financial investments, or new facilities. Rather than comprehensively covering the industry or its participants, the list highlights consequential changes.

Facility Name	Website	Significant Updates
Advanced Fiber Resources (AFR)	https://www.fiber-resources.com/	Founded AFR Thailand[a]
Advanced MicroFoundry (Singapore)	https://www.advmf.com/	Acquired by GlobalFoundries[b]
AIM Photonics	https://www.aimphotonics.com/	$27.5 million expansion in NY[c]
Ayar Labs	https://ayarlabs.com/	$155 million investment[d]
Bay Photonics	https://www.bayphotonics.com/	Acquired by AMS Technologies[e]
Benchmark	https://www.bench.com/	Opening large facility in Penang, Malaysia near semiconductor manufacturers[f]
CCRAFT	https://www.ccraft.com/	New addition
CEA-Leti	https://www.leti-cea.com	Opened a 2,000 sqm cleanroom focused on semiconductor development[g]
Coherent	https://www.coherent.com/	Recently sold a number of business capabilities[h]
CSEM	https://www.csem.ch/	Spun off CCRAFT to focus on high volume TFLN production[i]
Dream Photonics	https://dreamphotonics.com	Received 1.1 million CAD from Canada for hardware acquisitions and workers[j]
Enablence	https://www.enablence.com/	Completed $51 million recapitalization[k]
Fabrinet	https://fabrinet.com/home	Began construction on Chonburi Building 10 in 2025, adding 2 million square feet[l]
ficonTEC	https://www.ficontec.com/	Acquisition by RoboTechnik completed in 2025[m]
FormFactor	https://www.formfactor.com/	Acquired Keystone Photonics[n]

[100] QED-C, *Photonic Integrated Circuits for Quantum Applications: Challenges and Opportunities* (SRI International, November 2023), https://quantumconsortium.org/PICs23.

Facility Name	Website	Significant Updates
Fraunhofer HHI	https://www.hhi.fraunhofer.de/en/index.html	Launched the IGNITE innovation cluster to support shared test infrastructure and collaboration[o]
Freedom Photonics	https://freedomphotonics.com/	Acquired by Quantum Computing Inc[p]
GlobalFoundries	https://gf.com/	Acquired Advanced Micro Foundry[q]
GXC	https://gxc.io	Sold photonics division to ORCA Computing then was later acquired[r]
Honeywell	https://www.honeywell.com/us/en	Honeywell's subsidiary Quantinuum had its IPO in June of 2026[s]
HRL Laboratories	https://www.hrl.com/	Opened Camarillo facility to strengthen U.S. infrared hardware supply and consolidate semiconductor research[t]
HyperLight	https://hyperlightcorp.com/home	Raised more than $100 million in successive series rounds[u]
IHP	https://www.ihp-microelectronics.com/	Received €4.1 million as part of the APECS Pilot[v]
III-V Labs	https://www.3-5lab.fr/index.php	Joined the EU "PhotonHub PHACTORY" initiative[w]
IMEC	https://www.imec-int.com/en	Selected to coordinate the EU Chips Design Platform Program[x]
Infinera	https://www.infinera.com/	Acquired by Nokia[y]
Keysight	https://www.keysight.com/us/en/home.html	New addition
LIGENTEC	https://www.ligentec.com/	With X-FAB, began offering volume scaling for SOI and TFLN in 2026[z]
LioniX	https://www.lionix-international.com/	Moved to new facility to expand capabilities[aa]
OpenLight	https://openlightphotonics.com/	Raised a $34 million Series A[bb]
PhIX Photonics Assembly	https://www.phix.com/	Announced a partnership with Lightmatter to scale photonics integration[cc]
Qu-PIC	https://www.qu-pic.eu/	New addition
SkyWater	https://www.skywatertechnology.com/	Acquired by IonQ[dd]

Facility Name	Website	Significant Updates
SMART Photonics	https://smartphotonics.nl/	Supporting the construction of a €150 million 6-inch InP factory for photonics[ee]
Thorlabs Quantum Electronics	https://www.thorlabs.com/	Acquired Nu Opto[ff]
Tower Semiconductor	https://towersemi.com/	Committed $3 billion to silicon photonics manufacturing in Japan[gg]
Tyndall National Institute	https://www.tyndall.ie/	Received €100 million from the Irish government to expand its capabilities[hh]
UCSB Nanofab facility	https://www.nanotech.ucsb.edu/	Opened new facility with $60 million of nanofabrication equipment[ii]
Vanguard Automation GmbH	https://www.vanguard-automation.com/	Acquired by Mycronic[jj]
VTT	https://www.vttresearch.com/en	Joined the €400 million PIXEurope Initiative[kk]
X-Celeprint	https://x-celeprint.com/	Acquired advanced production capabilities from X-Display[ll]
X-Fab	https://www.xfab.com/	Entered into a few partnerships to expand photonics technologies[mm]

[a] "AFR Thailand Founded," Advanced Fiber Resources Milan, December 1, 2023, https://www.afrmilan.com/en/news-n880.html.

[b] "GlobalFoundries Acquires Advanced Micro Foundry, Accelerating Silicon Photonics Global Leadership and Expanding AI Infrastructure Portfolio," GlobalFoundries, November 18, 2025, https://gf.com/news-and-events/news/globalfoundries-acquires-advanced-micro-foundry-accelerating-silicon-photonics-global-leadership-and-expanding-ai-infrastructure-portfolio/.

[c] AIM Photonics, "New York State Photonics Board Approves $27.5M investment in AIM Photonics' Test, Assembly and Packaging Facility," March 10, 2026, https://www.aimphotonics.com/news/nys-photonics-board-approves-tap-investment.

[d] Ayar Labs, "Ayar Labs, with Investments from AMD, Intel Capital, and NVIDIA, Secures $155 million to Address Urgent Need for Scalable, Cost-Effective AI Infrastructure," December 11, 2024, https://ayarlabs.com/news/ayar-labs-155m-series-d-to-address-ai-infrastructure-includes-amd-intel-capital-nvidia/.

[e] "AMS Technologies Acquires Bay Photonics," *Photonics Spectra*, April 2026, https://www.photonics.com/Articles/AMS-Technologies-Acquires-Bay-Photonics/a72155.

[f] "Penang, Malaysia," Benchmark Asia, accessed July 6, 2026, https://www.bench.com/penang-malaysia.

[g] Alexa Hornbeck, "CEA-Leti Unveils 2,000 sqm Cleanroom to Drive Next-Generation Semiconductors," Cleanroom Technology, February 12, 2026, https://cleanroomtechnology.com/cea-leti-unveils-2-000-sqm-cleanroom-to-drive-next.

[h] Coherent, "Coherent Announces Agreement to Sell Aerospace and Defense Business to Advent for $400 Million," August 13, 2025, https://www.coherent.com/news/press-releases/coherent-announces-agreement-to-sell-aerospace-and-defense-business-to-advent; Coherent, "Coherent Announces Agreement to Sell Materials Processing Tools Product Division to Bystronic," October 31, 2025, https://www.coherent.com/news/press-releases/coherent-announces-agreement-to-sell-mMaterials-processing-tools-product-division-to-bystronic; Coherent, "Coherent Announces Sale of UK Manufacturing Facility Following Strategic Review," September 27, 2024, https://www.coherent.com/news/press-releases/coherent-announces-sale-of-uk-mfg-facility.

[i] "First Production-Ready TFLN Photonic Foundry Emerges from CSEM Spin-Off," CSEM, May 12, 2025, https://www.csem.ch/en/press/tfln-photonic-foundry-emerges-from-csem-spin-off/.

[j] Pacific Economic Development Canada, "Accelerating Commercialization and Adoption of AI and Quantum Technologies in British Columbia," Government of Canada, May 11, 2026, https://www.canada.ca/en/pacific-economic-development/news/2026/05/accelerating-commercialization-and-adoption-of-ai-and-quantum-technologies-in-british-columbia.html.

[k] "Enablence Announces Comprehensive $51 Million Recapitalization Transaction," Enablence Technologies Inc., April 4, 2025, https://static1.squarespace.com/static/6011d25cd19b9f108779996d/t/67f4404597ced37a5ece9253/1744060485698/Enablence+Announces+Comprehensive+%2451+Million+Recapitalization+Transaction.pdf.

[l] "Our History," Fabrinet, accessed August 24, 2026, https://fabrinet.com/about/history.

[m] "RoboTechnik Intelligent Technology Co., LTD Completed the Acquisition of Remaining 6.97% Stake in ficonTEC Service GmbH and ficonTEC Automation GmbH from Elas Technologies Investment GmbH.," Market Screener, May 7, 2025, https://www.marketscreener.com/quote/stock/ROBOTECHNIK-INTELLIGENT-T-103585612/news/RoboTechnik-Intelligent-Technology-Co-LTD-Completed-the-acquisition-of-remaining-6-97-stake-in-fi-49903539/.

[n] FormFactor, "FormFactor Expands Silicon Photonics Test Capabilities With Acquisition of Keystone Photonics," December 15, 2025, https://www.formfactor.com/press-release/formfactor-expands-silicon-photonics-test-capabilities-with-acquisition-of-keystone-photonics/.

[o] "IGNITE," Fraunhofer HHI, 2026, https://www.hhi.fraunhofer.de/en/ignite.html..

[p] Freedom Photonics, "Freedom Photonics Joins Quantum Computing Inc., Advancing Integrated Photonic Systems," February 2, accessed August 24, 2026, https://freedomphotonics.com/news/freedom-photonics-joins-quantum-computing-inc-advancing-integrated-photonic-systems/.

[q] GlobalFoundries, "GlobalFoundries Acquires Advanced Micro Foundry, Accelerating Silicon Photonics Global Leadership and Expanding AI Infrastructure Portfolio," November 18, 2025, https://gf.com/news-and-events/news/globalfoundries-acquires-advanced-micro-foundry-accelerating-silicon-photonics-global-leadership-and-expanding-ai-infrastructure-portfolio/.

[r] "ORCA Acquires Integrated Photonics Division of GXC," *Photonics Spectra*, January 2024, https://www.photonics.com/Articles/ORCA-Acquires-Integrated-Photonics-Division-of-GXC/a69679; GXC, "Motive Companies Announces Acquisition of GXC," November 7, 2024, https://www.gxc.io/news/motive-companies-announces-acquisition-of-gxc/.

[s] Annie Palmer and Samantha Subin, "Quantinuum Closes Flat in Nasdaq Debut, After Upsized Offering," *CNBC*, June 4, 2026, https://www.cnbc.com/2026/06/04/quantinuum-qnt-stock-first-trade-ipo.html.

[t] HRL Laboratories, "HRL Laboratories Expands with New Camarillo Facility to Strengthen U.S. Infrared Hardware Supply Chain," April 28, 2025, https://www.hrl.com/news/2025/04/28/hrl-laboratories-expands-with-new-camarillo-facility-to-strengthen-u-s-infrared-hardware-supply-chain.

[u] Summit Partners, "HyperLight Accelerates Growth with $37M Funding Led by Summit Partners," September 23, 2024, https://www.summitpartners.com/news/hyperlight-accelerates-growth-with-37m-funding-led-by-summit-partners; "HyperLight Lands $80M in Latest Funding Round," *Photonics Spectra*, June 19, 2026, https://www.photonics.com/Articles/HyperLight-Lands-80M-in-Latest-Funding-Round/a72344.

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