WHITEPAPER →

Enabling High-Power Multi-Wavelength Optical Scale-Up for AI Datacenters

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1/ Executive Summary

The rapid expansion of artificial intelligence (AI) workloads, particularly large language models, is driving unprecedented demand for datacenter networking. Traditional copper-based interconnects, long the backbone of server-to-server communication, are increasingly limited by bandwidth, latency, and power constraints. As AI clusters scale beyond single racks, optical networking becomes essential to meet the performance requirements of multi-rack deployments.

Photon Bridge is uniquely positioned to enable this next-generation optical infrastructure. Our cantilever waveguide platform allows highly manufacturable, scalable multi-wavelength laser sources that meet the stringent demands of AI datacenter operators: high wall-plug efficiency, precise wavelength accuracy, high optical output power, and cost-effectiveness. With this technology, datacenter operators can adopt multi-wavelength dense wavelength division multiplexing (DWDM) networks ahead of the anticipated optical scale-up transition in 2028–2029.

By combining passive alignment of III-V lasers with a thick-film silicon interposer, our platform is highly scalable, enabling 8-, 16-, or 32-color architectures supporting **>30mW per color, per fiber,** representing approximately **2× higher optical power** than competing heterogeneous techniques using thin-film silicon photonics, with more than **25× relaxed fabrication tolerances**, and >**10x smaller form factors** compared to more conventional discrete solutions. Photon Bridge provides a practical, scalable pathway for optical interconnects to power the AI datacenters of tomorrow.

2/ Market Context
The AI Datacenter Challenge

AI workloads are growing at an unprecedented pace. Large language models, high-resolution vision models, and complex multi-modal systems are driving massive increases in datacenter traffic, especially between racks and within clustered nodes.

These workloads require:

- **High bandwidth**: Multi-rack communication must support tens to hundreds of terabits per second
- **Low latency**: Real-time inference and training are highly sensitive to interconnect delays
- **Energy efficiency**: Power costs dominate operational expenditure, making wall-plug efficiency critical

Copper-based interconnects, while inexpensive and mature, struggle to meet these demands in scale-up environments. Their inherent physical limitations - signal loss, thermal constraints, and crosstalk - create bottlenecks as racks are clustered to support larger AI models.

Industry projections indicate a shift to optical interconnects around 2028–2029, driven by the explosive growth of AI model sizes and the performance advantages of optical links in scale-up deployments. A critical feature of this transition is **dense wavelength division multiplexing (DWDM)**, which enables multiple data channels to share a single fiber, dramatically increasing bandwidth while reducing latency.

However, realizing this vision requires reliable multi-wavelength laser sources that meet strict technical requirements:

- **High optical output power**, so fewer light source fibers serve more optical engines, cutting costs while maintaining uptime
- **Precise wavelength control**, so each DWDM channel reliably reaches its engine, maximizing fiber efficiency
- **Manufacturability and cost-effectiveness** at datacenter scale
- **Highly integrated**, delivering a small form factor to not occupy expensive real estate in the rack
- **High wall-plug efficiency** and rock-solid **reliability** to reduce operational costs

Photon Bridge’s technology platform addresses these requirements head-on, providing the foundation for optical networks that can meet the demands of next-generation AI datacenters.

3/

Technical Challenge Multi-Wavelength Laser Sources for AI Datacenters

The transition from copper to optical interconnects in AI datacenters is not limited by fiber, modulators, or switches. At the core of the challenge lies the laser source itself. As scale-up architecture evolves toward multi-rack clusters, laser sources must deliver a combination of performance characteristics that existing technologies struggle to achieve simultaneously.

Limitations of Existing Laser Architectures

Current approaches to multi-wavelength laser integration face fundamental trade-offs:

- **Heterogeneous/Thin-film silicon photonics** enable tight integration but suffer from limited optical power handling and tight fabrication tolerances, reducing system robustness and limiting manufacturing scalability
- **Discrete laser assemblies** occupy more rack space, rely on active alignment and complex packaging, resulting in higher cost, lower scalability, and limited compatibility with high-volume manufacturing
- **Monolithic** multi-wavelength lasers require substantial amounts of III-V material, increasing cost and limiting scalability. As the number of wavelengths grows, yield and thermal management become progressively more challenging. In addition, the wavelength multiplexer needed to combine multiple wavelengths is difficult to implement due to limited process control in epitaxial growth.

As DWDM channel counts increase, these limitations become more pronounced. The industry requires a fundamentally different approach that decouples wavelength scaling from cost, yield, and manufacturability constraints.

> Photon Bridge's cantilever waveguide-based technology platform was developed specifically to address these challenges, enabling a new class of scalable, manufacturable multi-wavelength laser sources optimized for AI datacenter applications.

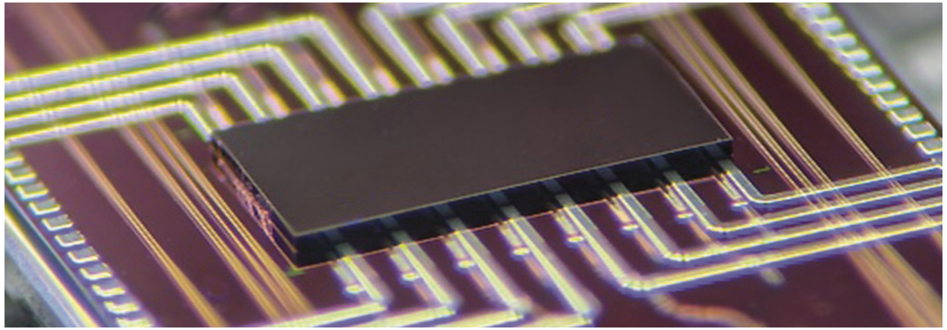
4/ Photon Bridge Technology Platform

Photon Bridge has developed a laser integration platform purpose-built for scalable, multi-wavelength optical sources in AI datacenter environments. The **key technology differentiator is a flexible silicon cantilever waveguide** interface that enables highly accurate passive optical alignment using standard flip-chip assembly tools. This approach decouples optical precision from mechanical placement accuracy, unlocking both manufacturability and scalability.

Cantilever Enables Manufacturable Laser-Silicon Integration

At the core of the Photon Bridge platform is a cantilever-enabled silicon interface that makes high-precision laser integration compatible with high-volume manufacturing. The cantilever waveguides are engineered to resolve the intrinsic placement limitations of standard flip-chip assembly while maintaining excellent optical performance.

Photon Bridge 8 wavelength DFB array integrated on silicon interoposer



In conventional OSAT environments, flip-chip bonders typically achieve placement accuracy on the order of ~2 µm. Photon Bridge's mechanically compliant cantilever waveguides flex and compress during bonding, converting this mechanical tolerance into **<200 nm optical alignment accuracy** at the laser–silicon interface. This enables true passive optical alignment using industry-standard flip-chip tools, eliminating the need for active alignment or post-bond tuning.

The same cantilever structure supports a well-controlled butt-coupled optical interface between the silicon waveguides and III-V (InP) laser facets, delivering:

- <1 dB insertion loss per interface
- Angled facets with anti-reflection coatings
- Back-reflection below −40 dB, supporting stable laser operation

By achieving optical precision mechanically rather than procedurally, Photon Bridge enables high-yield, low-cost assembly at scale. Multiple lasers can be bonded to a single silicon interposer using standard OSAT workflows, allowing scalable integration of 8-, 16-, or 32-wavelength DWDM sources without specialized tooling or process complexity, delivering:

- **>480 laser bonding events per hour**, delivering high-volume, low-cost assembly
- Predictable yields for 8-, 16-, and 32-channel systems

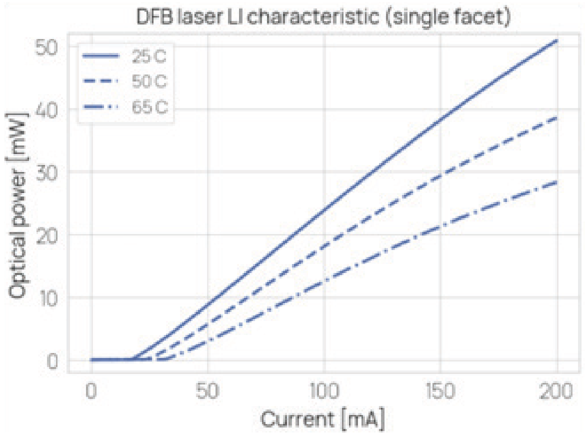
To validate this approach in practice, Photon Bridge has applied the cantilever-enabled integration process to its first bonded wafers using industry-standard assembly tools. The resulting bonding yield data confirms that passive alignment, low-loss coupling, and high placement tolerance can be achieved simultaneously, providing early evidence that the platform is well suited for high-volume manufacturing.

High Power Laser Integration on Silicon

Photon Bridge's platform enables high-power III-V lasers to be bonded with both facets coupled to silicon, supporting scalable DWDM modules with up to 32 wavelengths.

- **Dual-facet integration:** Both facets are connected, enabling efficient and scalable light extraction
- **High optical power**: Laser bonding supports >50mW per color without compromising loss or stability
- **Scalable arrays**: Multiple lasers can be bonded on a single interposer, maintaining performance across 8-, 16-, or 32-channel DWDM configurations

Representative power-current curves illustrate the platform's ability to deliver high, uniform optical output in a robust, manufacturable configuration.



Photon Bridge
O-Band DFB Typical
Output Power Curves

Distributed Laser Power Boosts Reliability

Photon Bridge's architecture improves reliability by distributing optical power across multiple lasers. For example, an 8-color, 8-fiber source can be realized with multiple lasers, rather than relying on a single high-power DFB per channel.

This design reduces the **power density in each laser by 2x** compared to a conventional single-laser-per-color solution, lowering thermal stress and reducing the likelihood of facet degradation or accelerated aging. Lower power density also mitigates optical nonlinearity and back-reflection effects, contributing to more uniform performance over time and across the array.

> By combining distributed high-power bonding with integrated passive multiplexing, Photon Bridge delivers not only scalable DWDM performance, but also inherent reliability advantages that are critical for multi-rack AI datacenter deployments.

Integrated Wavelength Multiplexing, Power- and Thermal-Optimized Platform

A key requirement for next-generation DWDM AI networks is the ability to combine multiple wavelengths into a single optical waveguide at the laser source. Photon Bridge's platform naturally supports this by integrating passive wavelength multiplexing structures directly on the silicon interposer, alongside the cantilever-coupled III-V lasers.

Core technical advantages of Photon Bridge's approach are:

- **Thick silicon waveguides** (2x2 µm): Compared to thin-film platforms, these larger waveguides allow passive multiplexer structures that are 25× more robust to fabrication variations, improving yield, reliability, and manufacturability. They also support high optical power (> 1W, 50x more than thin film silicon), critical for multi-rack AI deployments.

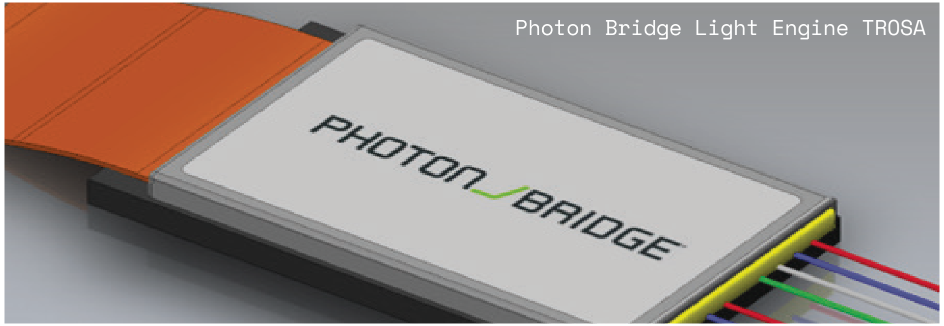
- **Matched temperature-dependent wavelength shift**: Photon Bridge aligns the thermal tuning of silicon waveguides and III-V lasers (InP) so that wavelength drift is minimized across operating temperatures. This reduces the need for complex thermal control, lowering cost and simplifying system design.

> The large waveguides and relaxed fabrication tolerances ensure robust operation of multiplexers and other passive photonic components across process and environmental variations.

5/ The AI Light Engine

Photon Bridge's platform translates directly into a scalable, high-performance External Laser Source (ELS) that meets the demands of next-generation AI datacenters. The ELS is designed to deliver:

- **>30 mW per color DWDM lasers**, so fewer light source fibers serve more optical engines, cutting costs while maintaining uptime
- **Scalable channel counts**: 8-, 16-, or 32-wavelength configurations in a single module
- **Support for >100 Tbps interconnects** from a single ELS across multiple fibers



The Photon Bridge ELS provides several **practical benefits for system designers**:

- Scalable multi-channel DWDM: Easily scale from 8 to 32 colors without redesigning the module
- Uniform power and wavelength stability: Each wavelength is independently optimized for consistent performance
- Simplified integration: Multiplexing at the source reduces downstream optical complexity, lowering system cost and improving reliability

By delivering high-power, scalable DWDM lasers in a single module, Photon Bridge enables optical interconnect architectures that are compact, efficient, and capable of supporting the massive bandwidth requirements of AI scale-up networks.

6/ Future Outlook Optical Scale-Up in AI Datacenters

As AI workloads scale, multi-rack clusters will demand optical interconnects. DWDM will be central, enabling high bandwidth with low latency and power efficiency. Laser sources must scale in wavelength, power, and volume without increasing cost or reducing reliability.

Photon Bridge's roadmap aligns with this evolution:

- Scaling DWDM channels as demand grows
- Supporting higher optical power per wavelength
- Adapting to new wavelength grids and architectures

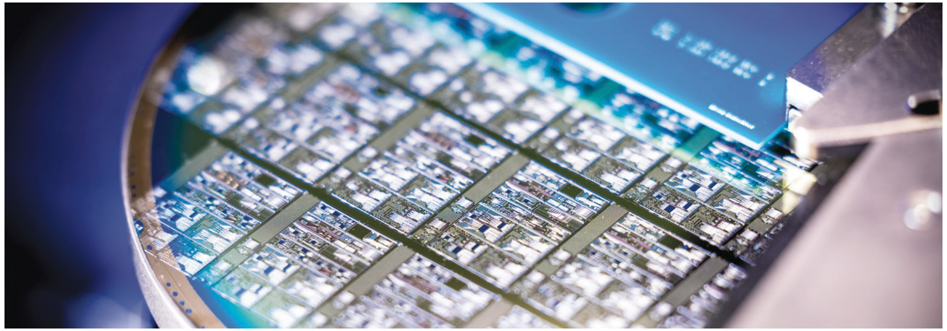
By focusing on manufacturability, scalability, and system performance, Photon Bridge is positioned to support optical scale-up adoption from early deployment to mainstream adoption.

7/ Conclusion

The transition from copper to optical interconnects in AI datacenters is a fundamental shift. Multi-wavelength DWDM architectures are the most viable solution for next-generation AI clusters, but only if laser sources can scale in performance, volume, and cost.

Photon Bridge addresses this challenge with a cantilever waveguide-based platform that delivers highly manufacturable, scalable multi-wavelength lasers. By mechanically resolving optical alignment, supporting high optical power, and enabling OSAT-compatible assembly, Photon Bridge provides a practical foundation for optical scale-up networking.

As AI datacenter architectures evolve, Photon Bridge ensures laser source technology will be an enabler of growth, not a limiting factor.



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