Docket #: S24-236

Enabling low-cost fiber optic systems by eliminating polarization sensitivity

Stanford scientists have designed a passive and active polarization-insensitive grating coupler that enables consistent fiber-to-chip light coupling regardless of input polarization state. These designs eliminate the need for expensive polarization-maintaining fibers and complex active tuning systems, significantly reducing costs and simplifying optical system requirements for semiconductor foundries.

Existing polarization-insensitive coupling solutions like polarization diversity or gradient-descent based stabilizers depend on multi-stage systems combining polarization splitting gratings, mode converters, and coherent combiners with complex computing algorithms. Each component must be individually optimized for high efficiency, creating significant design complexity and the complex computing algorithms create large computing overhead and often requires repeated reinitialization when the input polarization state changes. These approaches require additional costs, power consumption, latency related to computing overheads and reliability concerns, making these solutions impractical for many applications where the simplicity and cost advantages of standard single-mode fibers would otherwise make them the preferred choice. The technology entails passive and active implementations for polarization-insensitive couplings with much simpler configuration than conventional approaches.

Stanford researchers have designed a single passive grating coupler and an active single phase-detection based polarization stabilizer that works for linear polarization and arbitrary polarization states, respectively. These designs eliminate the need for multiple optical components and complex active control systems, reducing both manufacturing complexity and operational costs. The technology enables consistent performance when using inexpensive standard single-mode fibers instead of costly polarization-maintaining fibers, which can cost 10-20 times more. Simulations

demonstrate reliable coupling efficiency regardless of fiber polarization orientation, making it suitable for high-volume manufacturing. Consequently, this breakthrough can significantly reduce system costs and complexity for semiconductor foundries and optical device manufacturers while maintaining performance standards.

Stage of Development:
Proof of concept
Continued research – complete the demonstration of this idea by designing and verifying its desired functionality

Applications

- Fiber-to-chip coupling in photonic integrated circuits
- Optical communication systems using standard single-mode fibers
- Semiconductor foundry manufacturing of grating couplers
- High-volume optical device production requiring cost optimization

Advantages

- Eliminates need for expensive polarization-maintaining fibers (10-20x cost reduction)
- Single passive component replaces complex multi-element systems free from active tuning and power consumption requirements
- Active single phase-detection based polarization stabilizers with much simpler control scheme
- Consistent performance regardless of input polarization state
- Suitable for high-volume manufacturing processes
- Reduces system complexity and potential failure points

Patents

- Published Application: WO2026011144

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