A DSP-FREE CARRIER PHASE RECOVERY SYSTEM USING 16-OFFSET-QAM LASER FORWARDED LINKS FOR 400GB/S AND BEYOND

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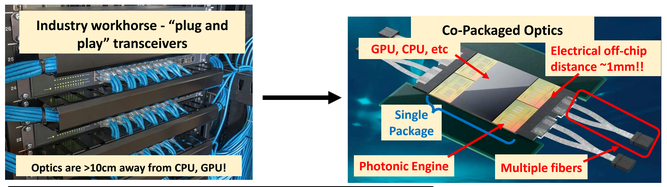
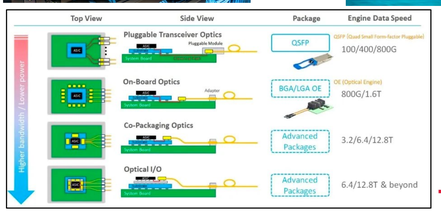
Introduction

- AI/ML accelerators, GPUs, and network switches now demand optical interconnects with tens of Tb/s capacity
- With circuits already near their speed limits, further scalability depends on advanced modulation and system-level innovations
- PMA-6/8 suffers from poor SNR, making coherent modulation schemes a more viable alternative
- Co-Packaged Optics (CPO) enables higher-order coherent modulation, such as 16-QAM, for increased data throughput
- DSP-based coherent links consume ~50pJ/bit, far exceeding the <1pJ/bit budget required for intra-datacenter links
- DSP is essential for long-haul communication but can be eliminated for energy-efficient rack-to-rack interconnects within datacenters
- Carrier phase recovery (CPR) remains necessary for phase and frequency compensation in coherent systems
- Analog CPR can replace power-hungry DSPs, enabling energy-efficient intra-datacenter interconnects
- Existing DSP-free CPR systems support only up to 4-QAM (QPSK), limiting the scalability of CPO-based coherent modulation



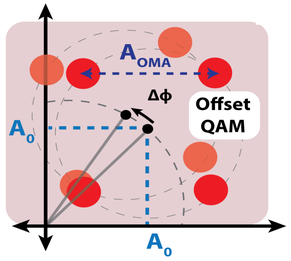


Project Overview

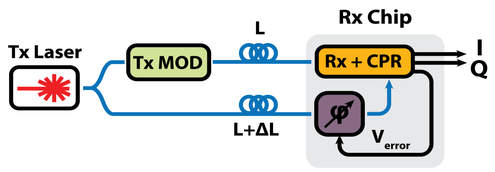
- We propose a DSP-free carrier phase recovery system that supports any QAM modulation level (4/16/64/256, etc.) without architectural modifications
- The proposed system supports offset-QAM modulation by introducing a controlled leakage of laser power into the transmitted optical signal
- System complexity can be further reduced using the laser forwarding technique, which eliminates the need for an extra laser at the receiver (Rx)
- Laser forwarding synchronizes the LO and Rx carrier frequencies, significantly reducing laser phase noise and requiring only phase compensation
- The chip is fabricated in Global Foundry's monolithic 45nm silicon photonics process

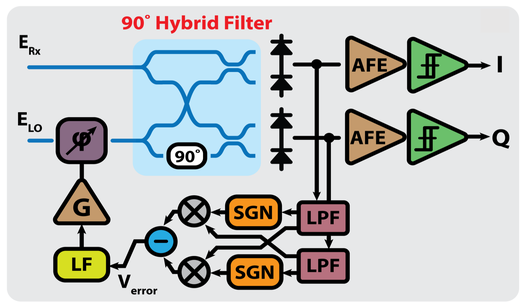
DSP-Free Carrier Phase Recovery

- Coherent modulation requires precise phase and frequency alignment between the Rx and LO
- Phase error between the Rx and LO can be detected from the average power difference between the I and Q paths

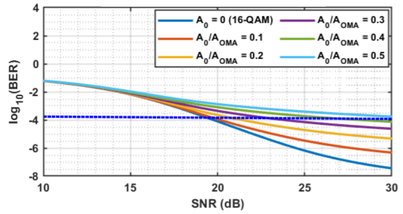


- $I_{avg}(\Delta\phi) = A_0\cos(\Delta\phi) + A_0\sin(\Delta\phi)$
- $Q_{avg}(\Delta\phi) = A_0\cos(\Delta\phi) - A_0\sin(\Delta\phi)$
- Error $(\Delta\phi) = I_{avg}(\Delta\phi) - Q_{avg}(\Delta\phi) = 2A_0\sin(\Delta\phi)$

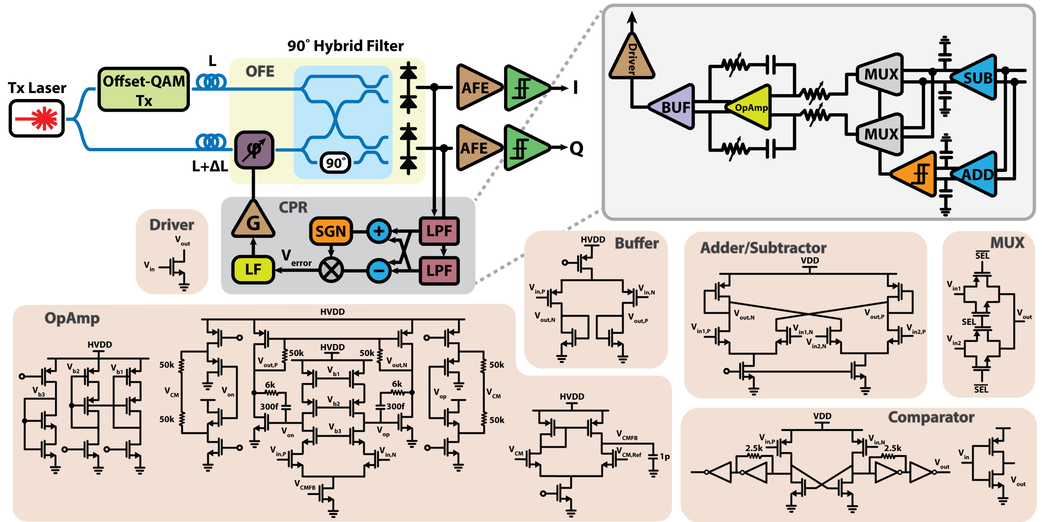


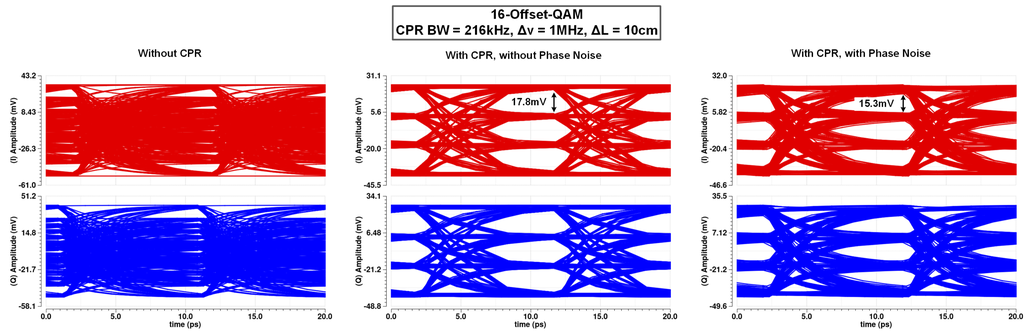


- The BER of the proposed offset-QAM modulation depends on the offset value (A_0)
- Increasing the offset results in a higher SNR penalty
- Minimizing the length mismatch between the Rx and LO improves BER performance
- The proposed system must meet the KP4 BER requirement



Proposed CPR System Architecture





Future Work, Acknowledgments, and References

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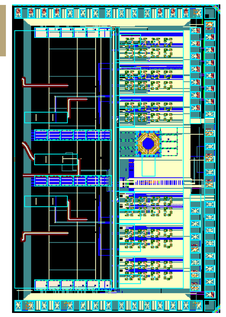

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