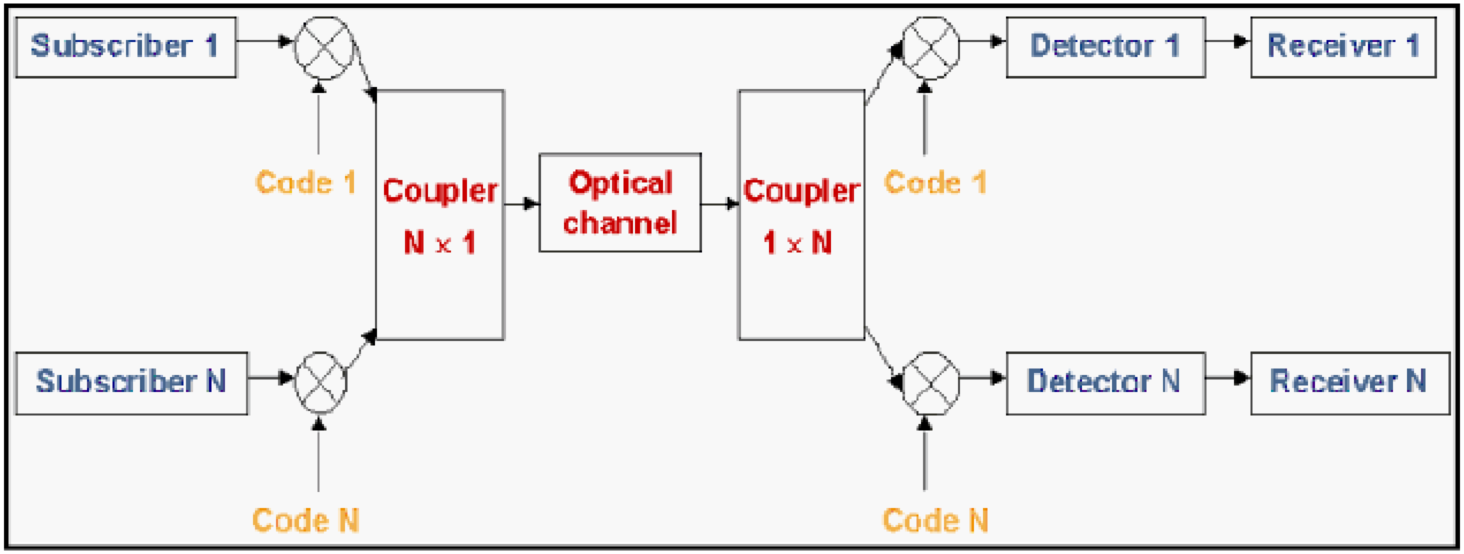
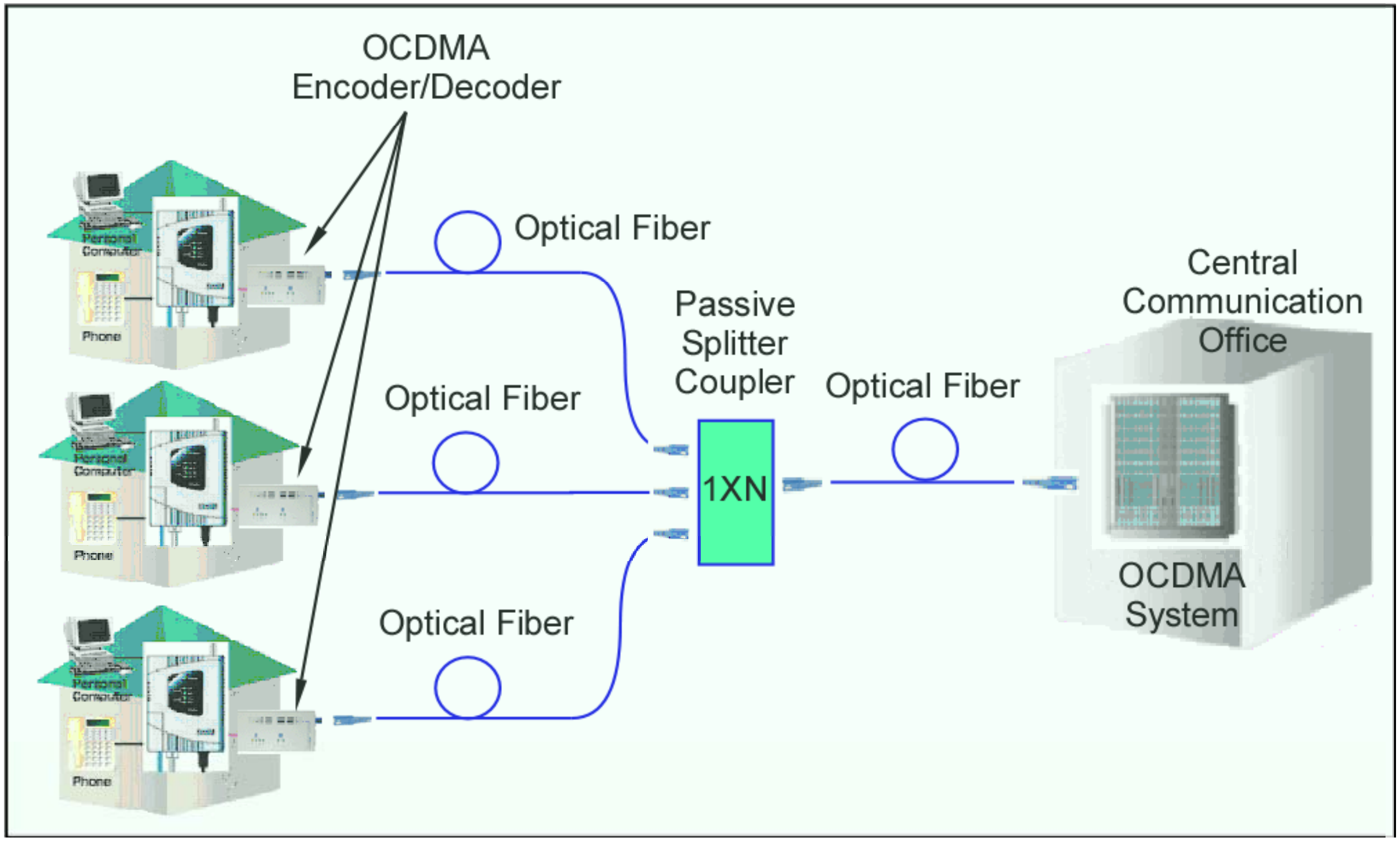
Principles of CDMA



Optical CDMA advantages:

- Perform signal encoding/decoding in optical domain directly – potentially high speed (>100Gbit/s).
- Avoid electrical/optical and optical/electrical conversion bottleneck.
- Efficient bandwidth utilization.
- Data format and protocol transparent – simplified architecture and network maintenance.
- Simplified network architecture, less equipment inventory, flexible, scalable network.

Fiber to the home (FTTH)



Challenges:

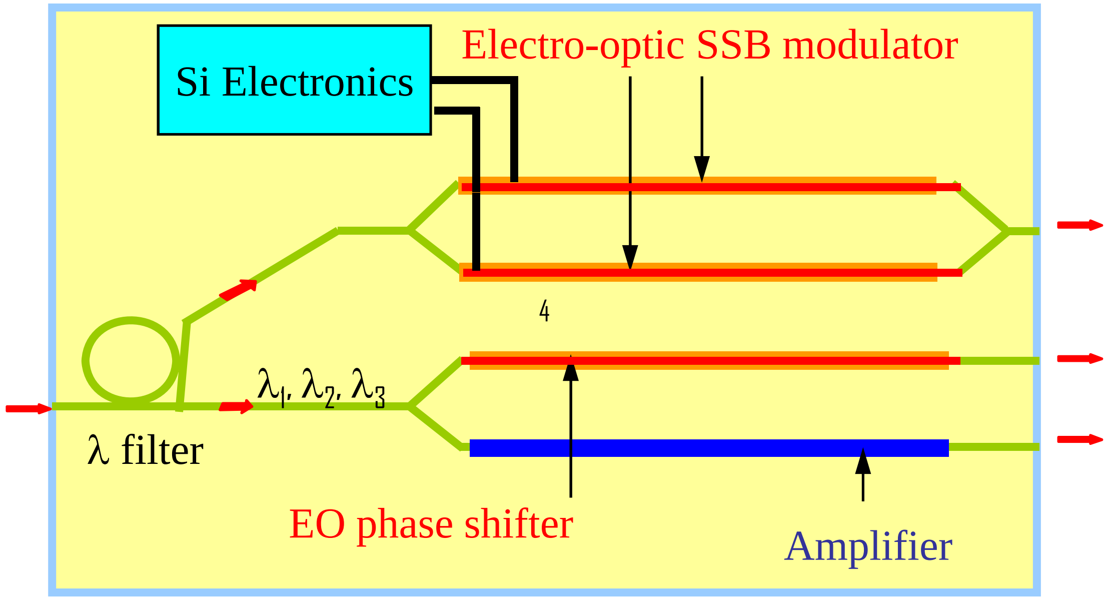
- Accurate and tunable phase control
- All-optical switch and amplitude modulation
- Integrated circuits with these functionalities

Polymeric waveguide based photonic circuits:

- Large electro-optic (EO) and Thermo-Optic coefficients:
  - polymer TO ~ -1.4 x 10^{-4}/°C; silica, T.O. ~ 1 x 10^{-5}/°C
  - Polymer EO ~ 80pm/V, LiNbO3 ~ 33pm/V
- Low dielectric constant -- Potentially high–speed operation:
  - polymer: ε_r ~ 2.3, Si: ε_r ~ 10
  - Capacitance ~ 5 times smaller than Si based circuits.

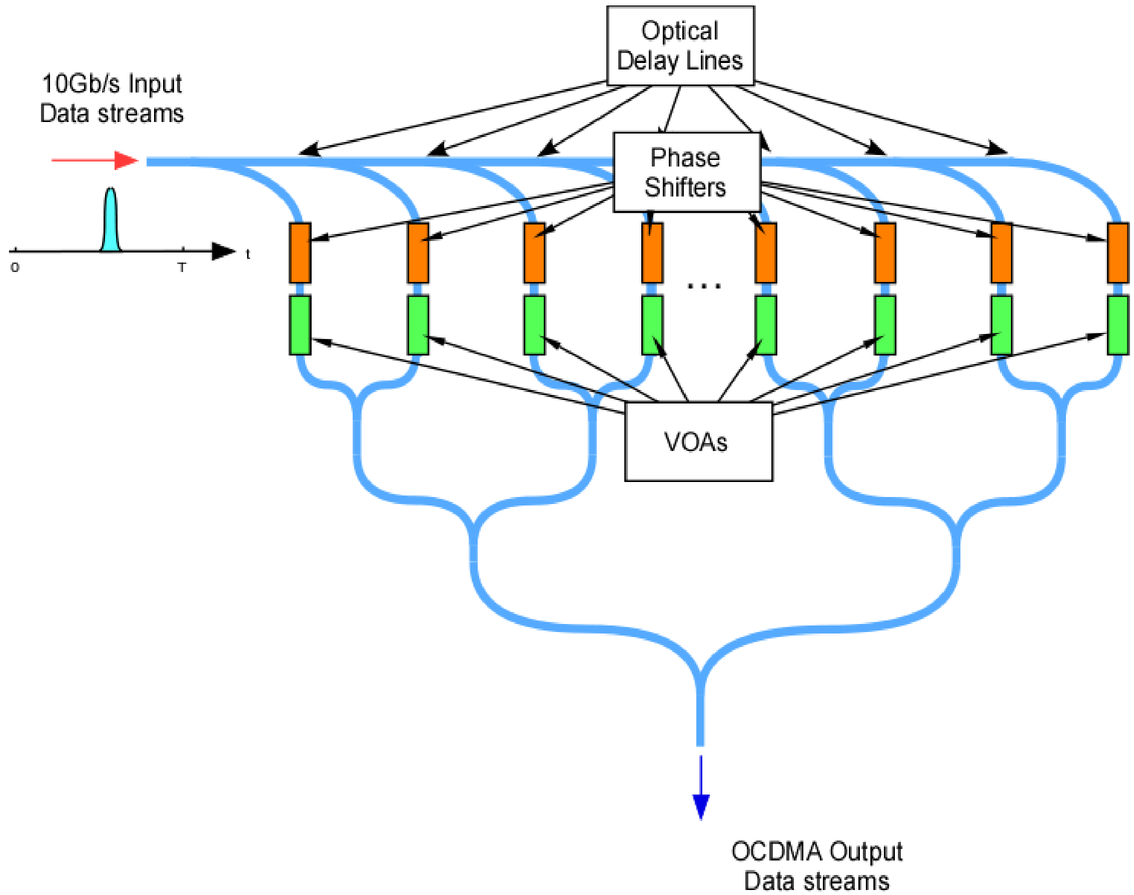
Polymeric waveguide based photonic circuits:

• Multifunction capability --- Photonic integrated circuits

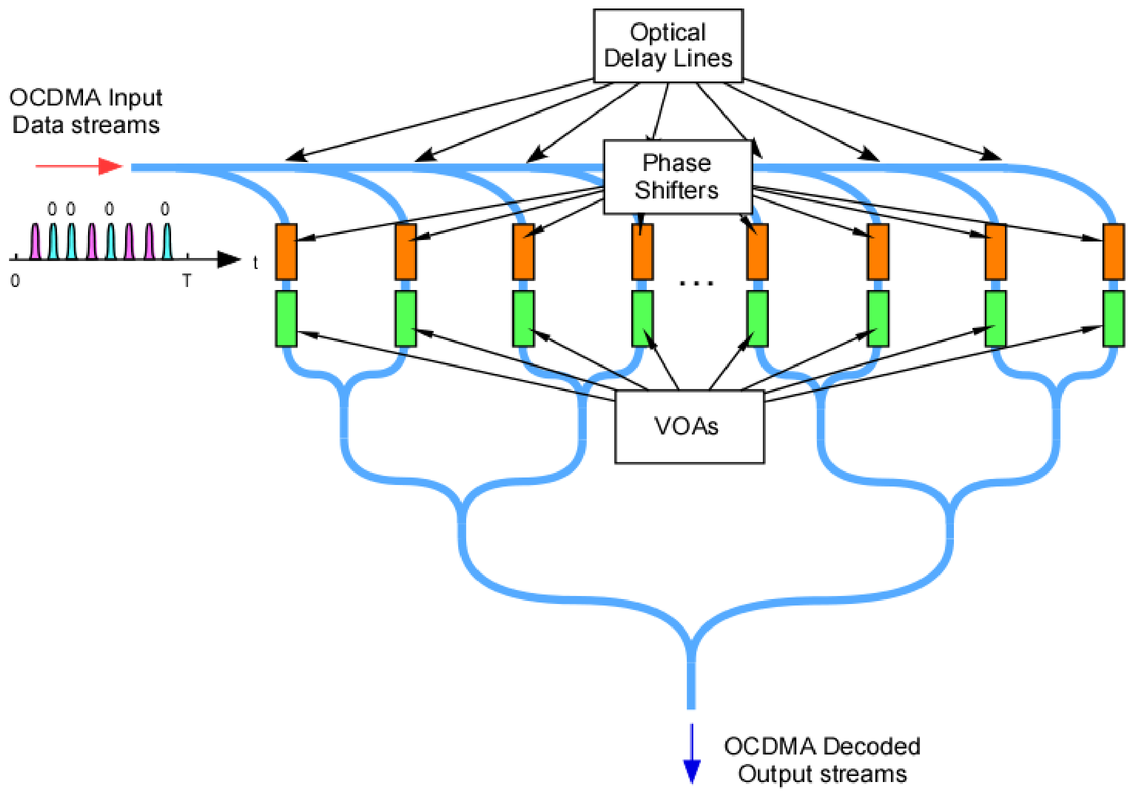


• Flexible substrate, low cost and relative simple fabrications

Fiber to the home (FTTH)



Polymeric waveguide based OCDMA decoder



Received signal SNR

Code length	No. of subscribers	No. of active users at BER 10^{-9}	Data Bit Rate per user (max.) (Mb/s)
31	33	2	322.5
127	129	4	78.7
511	513	15	19.5
1023	1025	29	9.7

- High bit error rate (BER) due to correction noise.
- Need long sequence to reduce the correction error.

Orthogonal Amplitude-phase Coding

$$R(\tau) = X_i(t) X_k(t-\tau)$$
$$= \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} b_n^i b_m^k u(t - mT_c) u(t - nT_c - \tau) = \delta_{i,k} \delta(\tau),$$

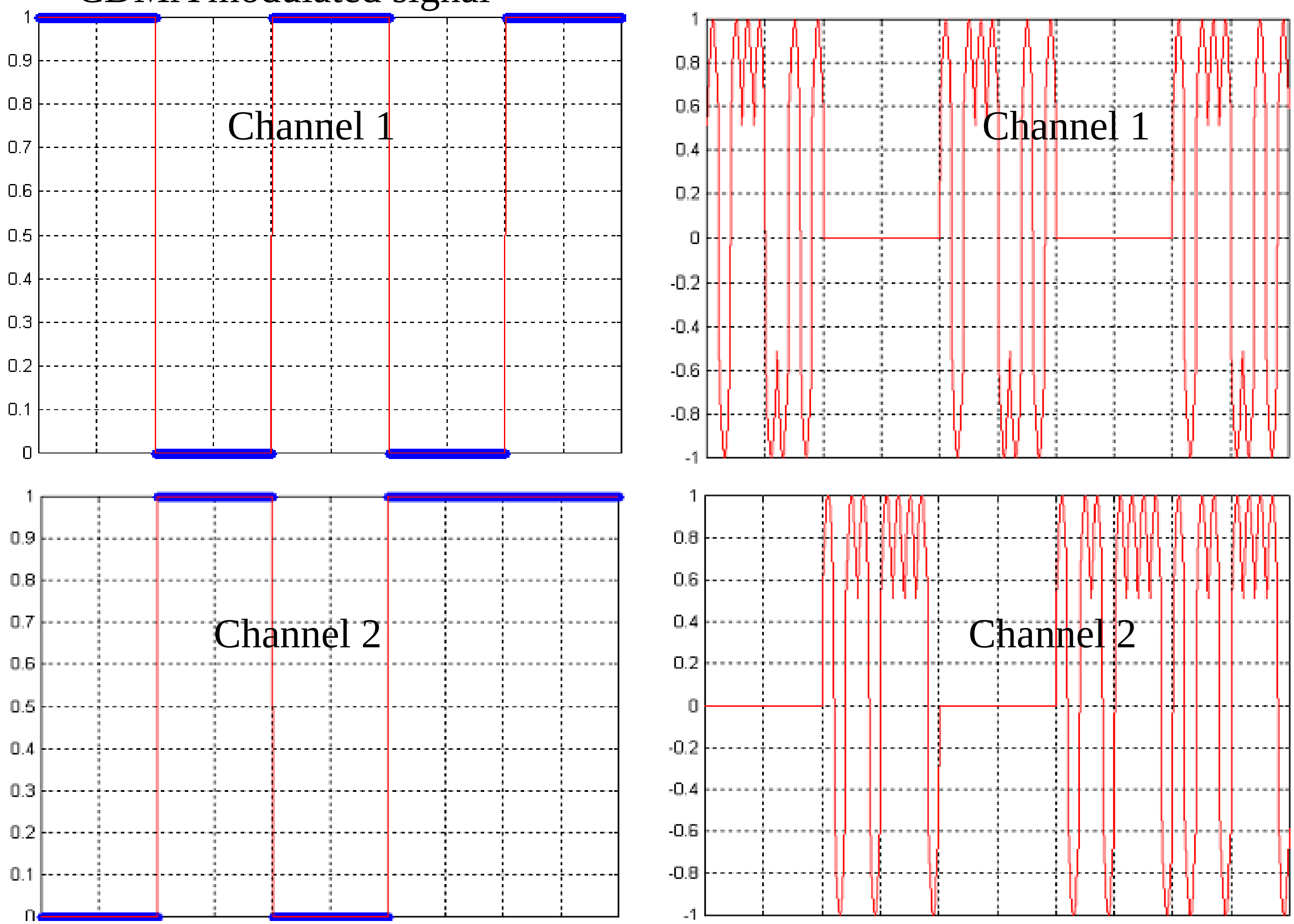
	Spreading and De-spreading using Gold codes														
Data	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Code	1	0	1	0	1	1	0	0	1	0	0	0	1	1	1
Coded data	1	0	1	0	1	1	0	0	1	0	0	0	1	1	1
$\Delta\theta$	π	0	π	0	π	π	0	0	π	0	0	0	π	π	π
Cross to auto correlation Ratio	0.7														

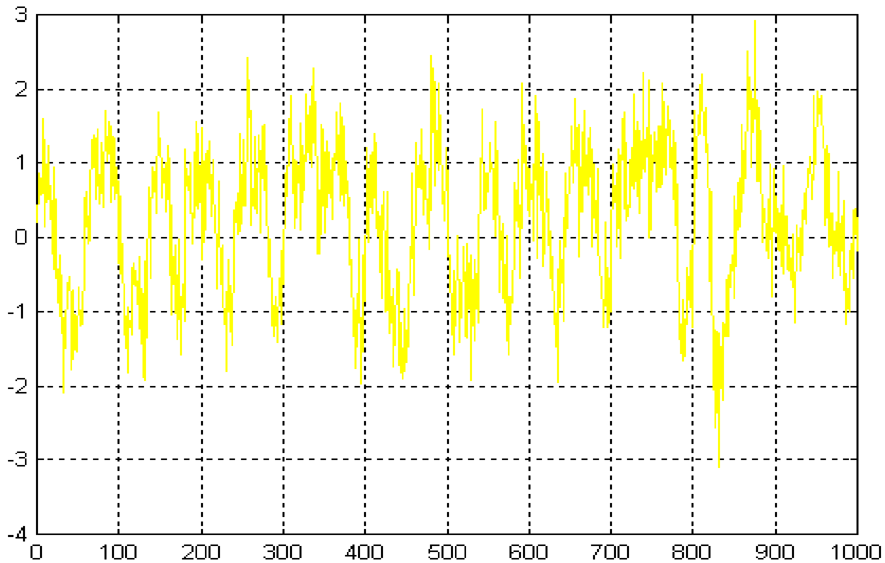
	Spreading and De-spreading using the proposed orthogonal codes														
Data	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Code	-0.3	-0.2	0.6	0.5	-0.3	-0.2	0.0	-0.3	0.1	-0.1	0.1	-0.1	0.2	0.0	0.0
Coded data	-0.3	-0.2	0.6	0.5	-0.3	-0.2	0.0	-0.3	0.1	-0.1	0.1	-0.1	0.2	0.0	0.0
$\Delta\theta$	π	π	0	0	π	π	0	π	0	π	0	π	0	0	0
Cross to auto correlation Ratio	<0.02														

Optical CDMA Modulation

CDMA modulated signal

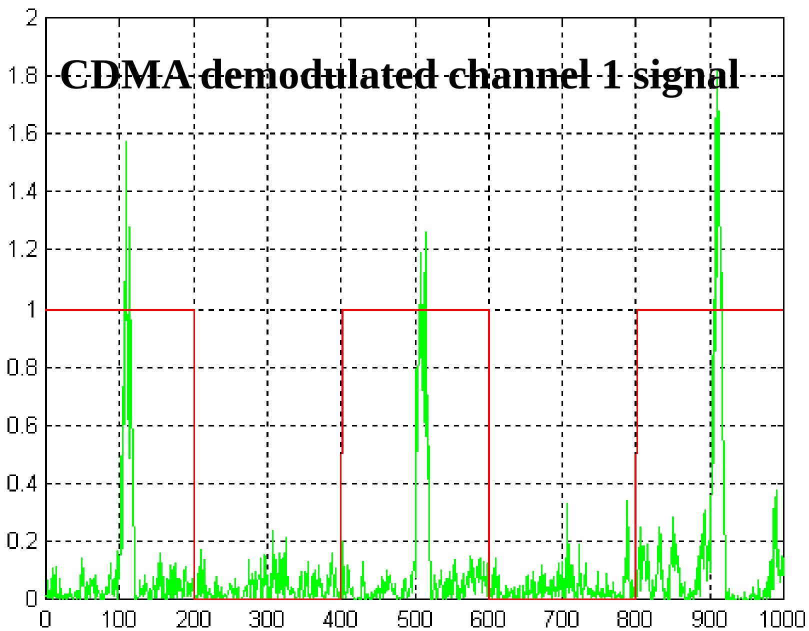
CDMA modulated signal

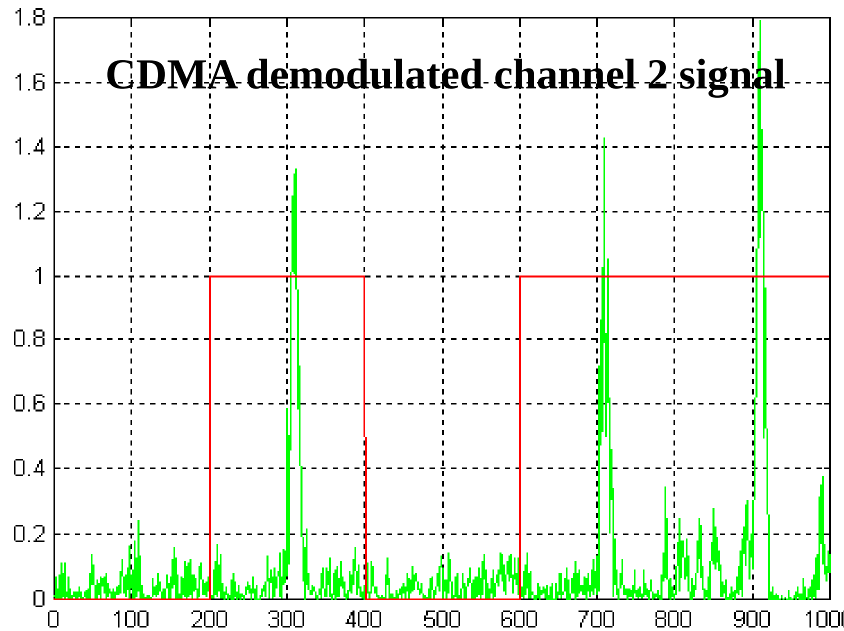




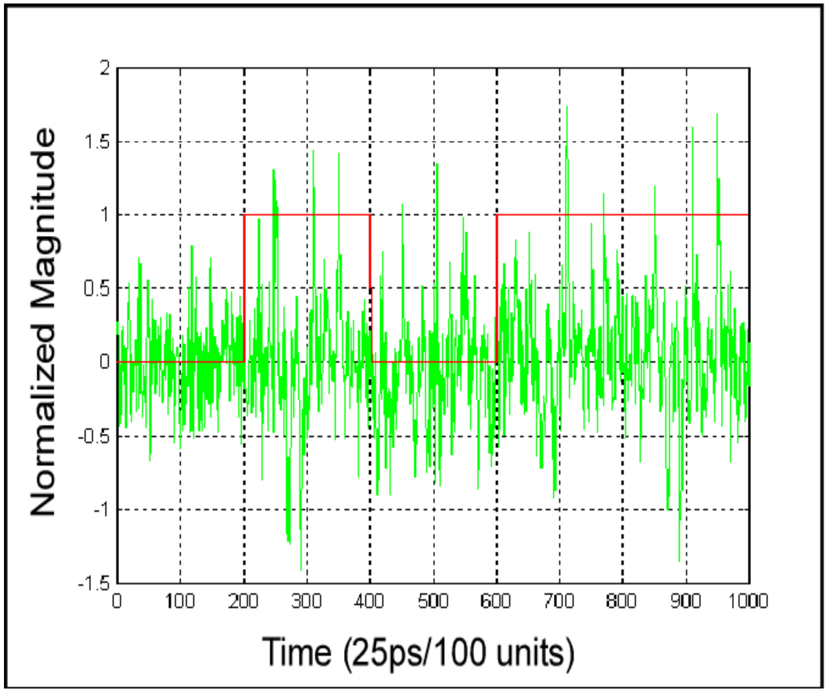
Received signal

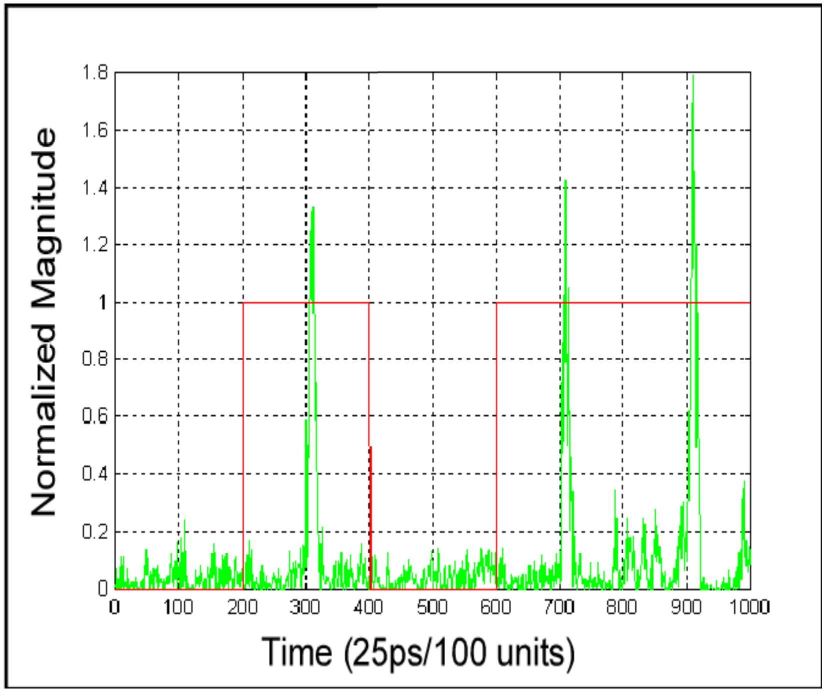
Time scale 25ps/100units





Polymer Waveguide optical Time Gate

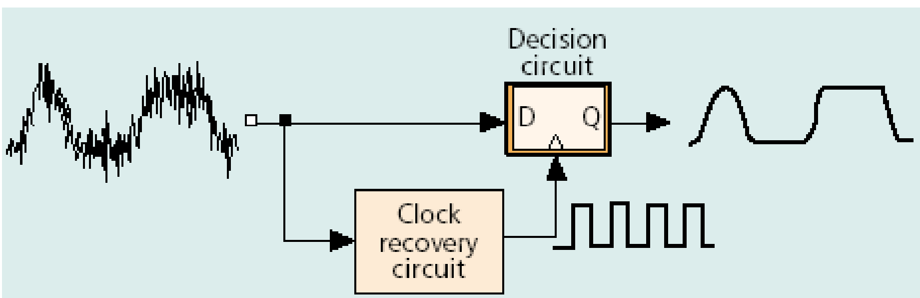


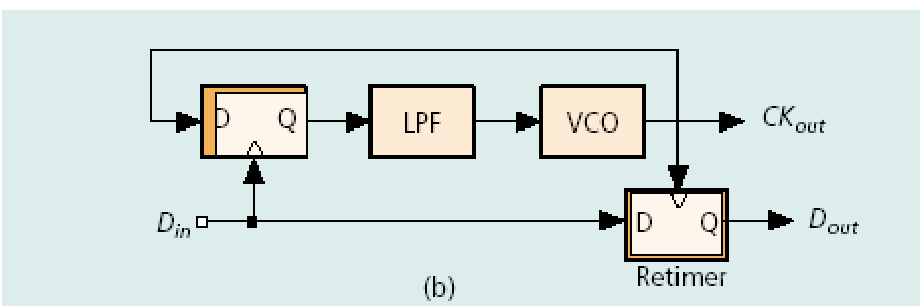


100Gb/s Tranceivers

Difficulties of traditional transceivers

- High-speed (>40Gb/s) external modulators not available.
- Extremely difficult to achieve CDR using high-bandwidth (>40GHz) electronic circuitry even with low k and scale VLSI technologies.
- SNR degradation for ultra-high frequency circuitry.
- Very expensive.





100Gb/s All-optical Transceiver Interface Module

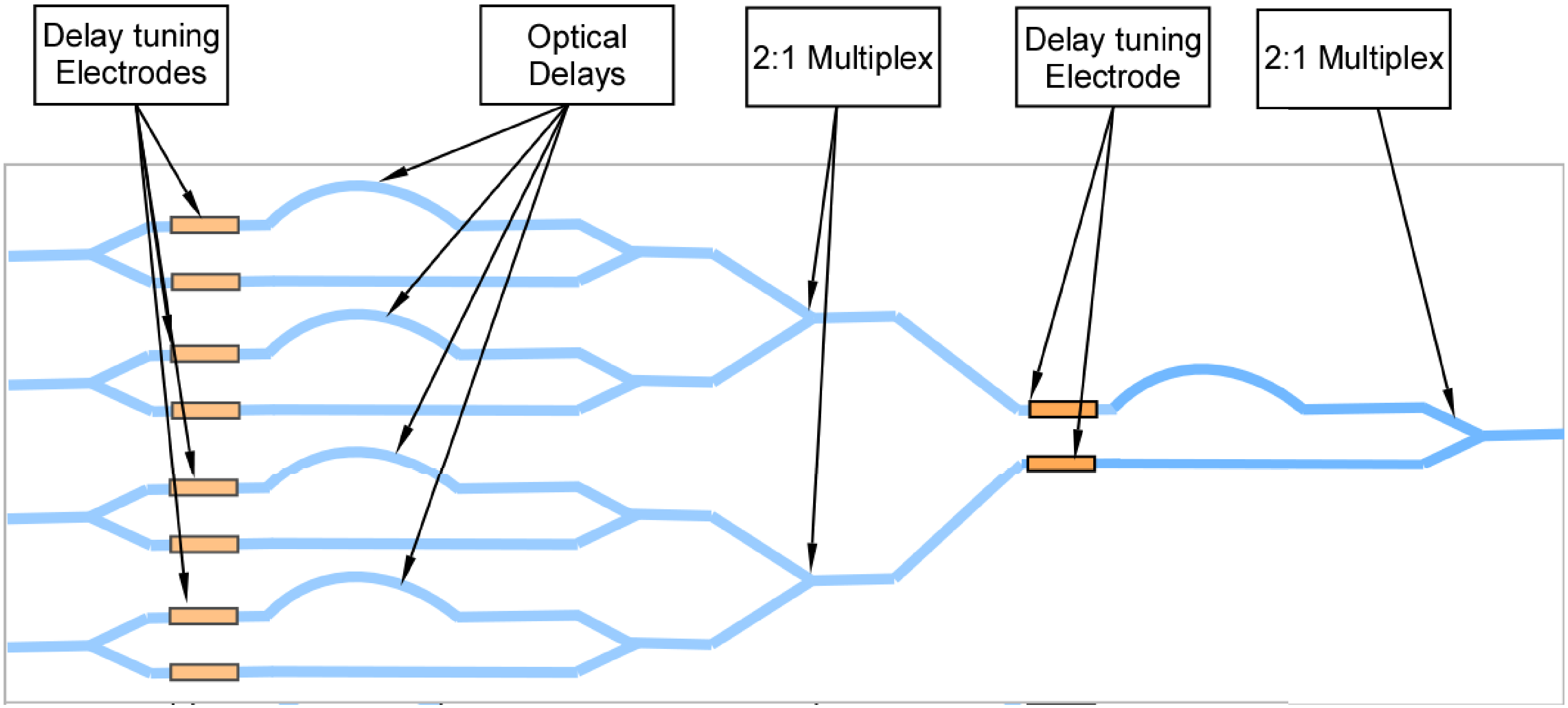
Why All-optical Module

1. Interface the relative slow electronics circuit.
2. Perform pulse reshape and retiming without OE-EO conversion.
3. Future all-optical packet routing.

Challenges:

1. 100GHz optical clock generation.
2. Optical threshold gate.
3. Re-shaping and re-timing.

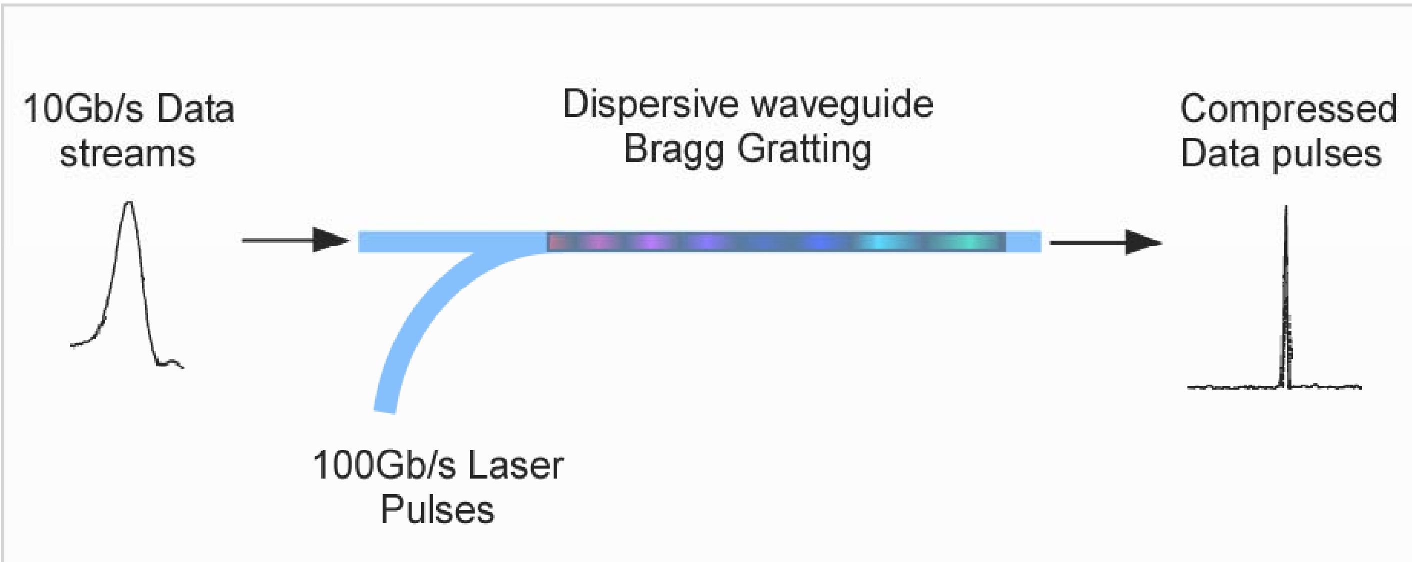
Architecture of 100Gb/s Transceiver Interface Module

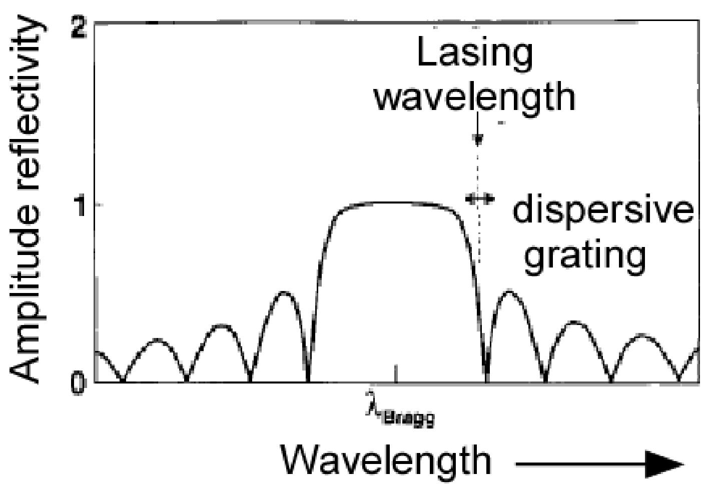


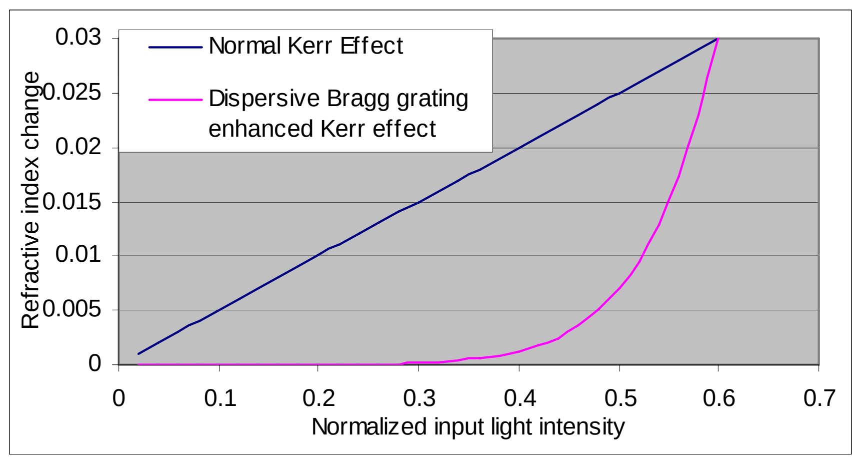
- Photonics integrated circuit approach
- Precisely controlled time delays

Architecture of 100Gb/s Transceiver Module

Pulse compressor:







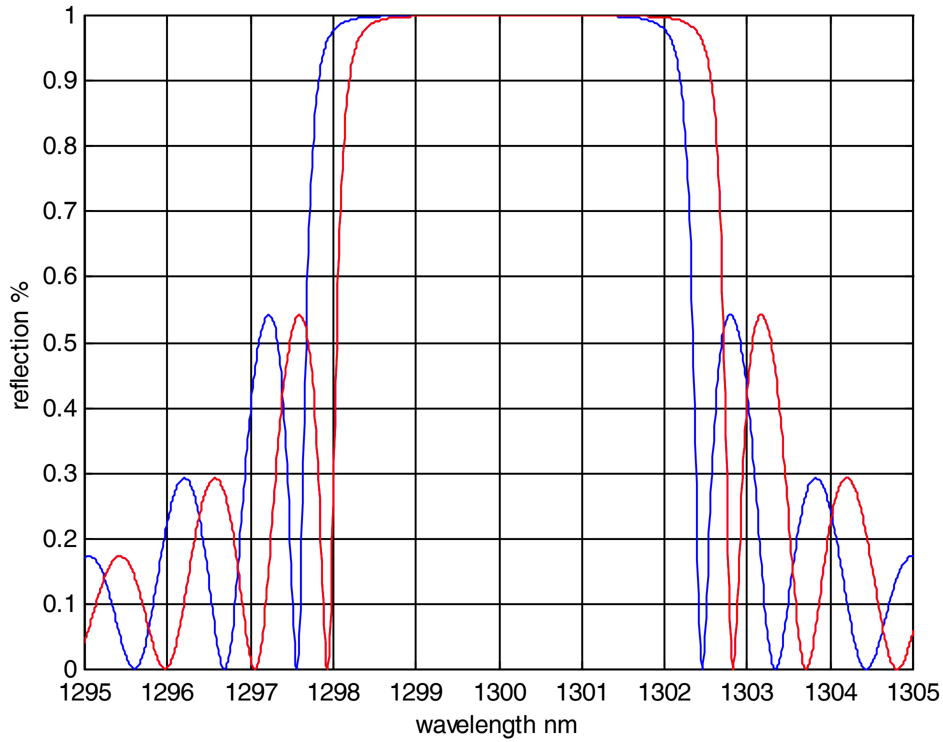
Kerr Nonlinearity in Semiconductors

Kerr Nonlinearity:

$$\Delta n = \lambda K E^2 = \propto I = n_2 I,$$

$n_2 \sim 3 \times 10^{-14}\ cm^2 / W$ in InP semiconductor

- Index change and tuning range:

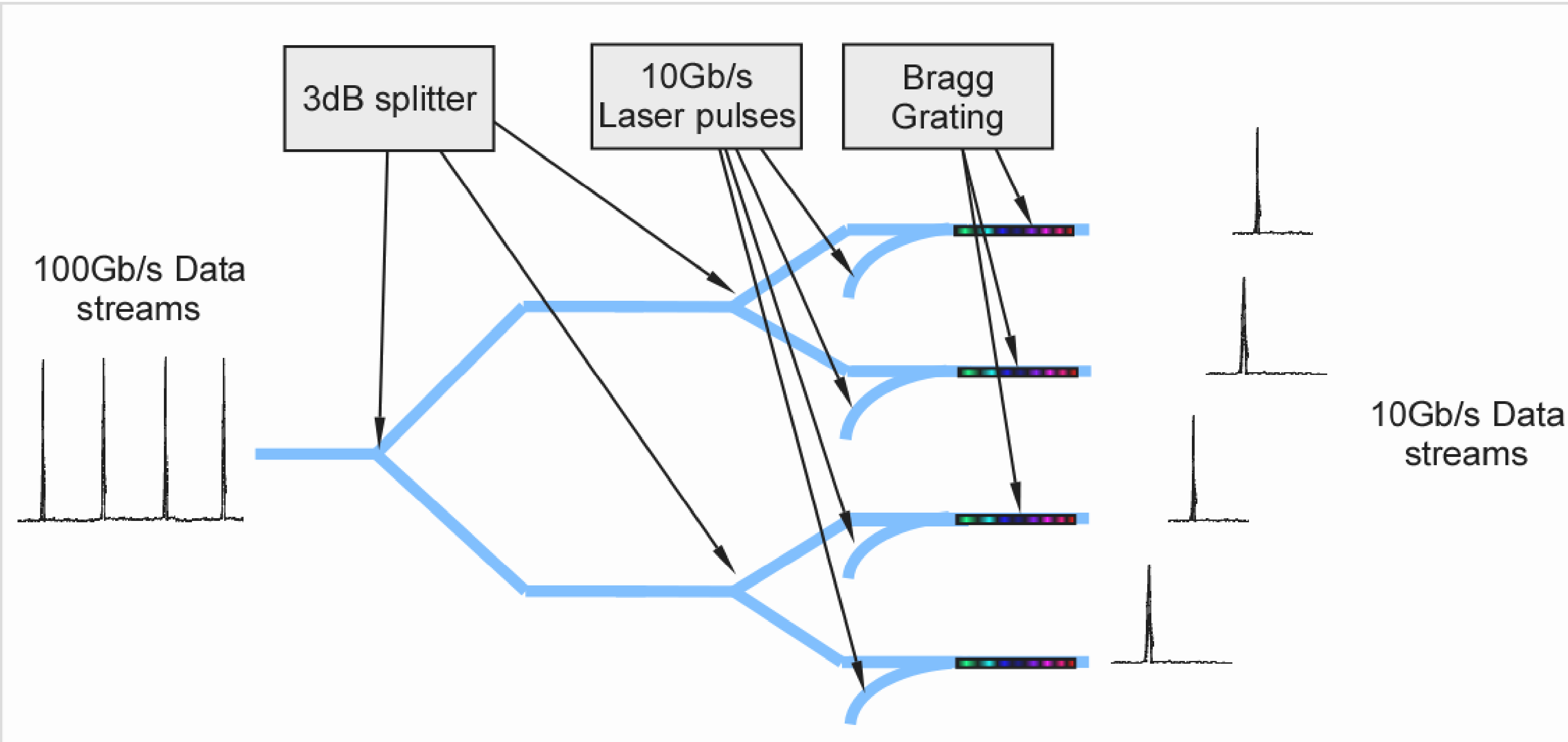


- For high index contrast (3.5:1), 10mW laser power induces index changes of 0.03.

- Pulse compression ratio >10.

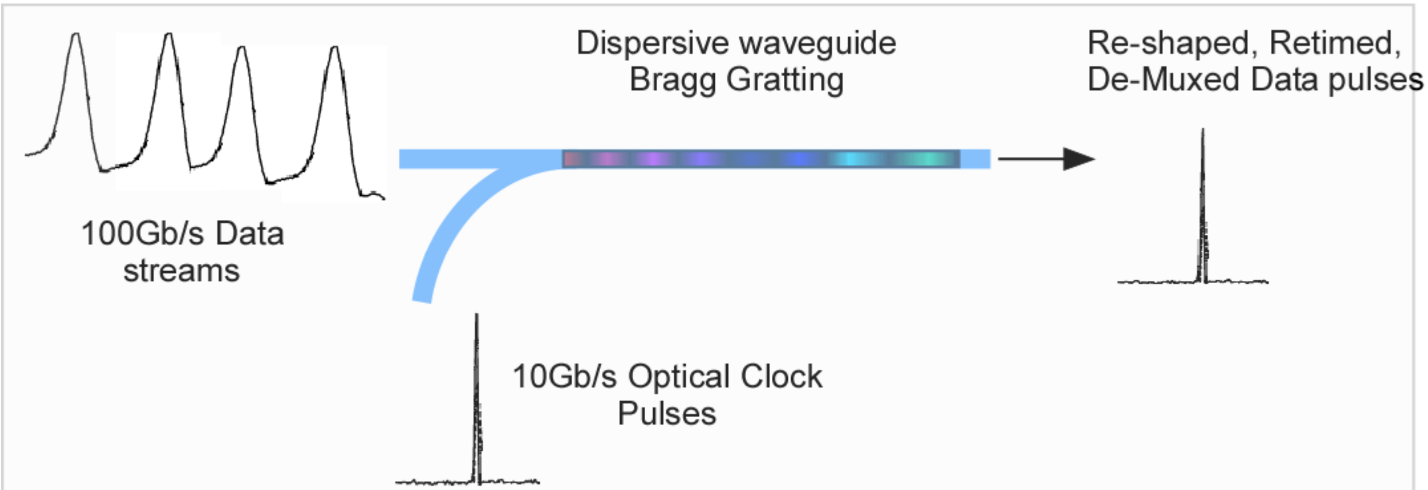
Architecture of 100Gb/s Transceiver Module

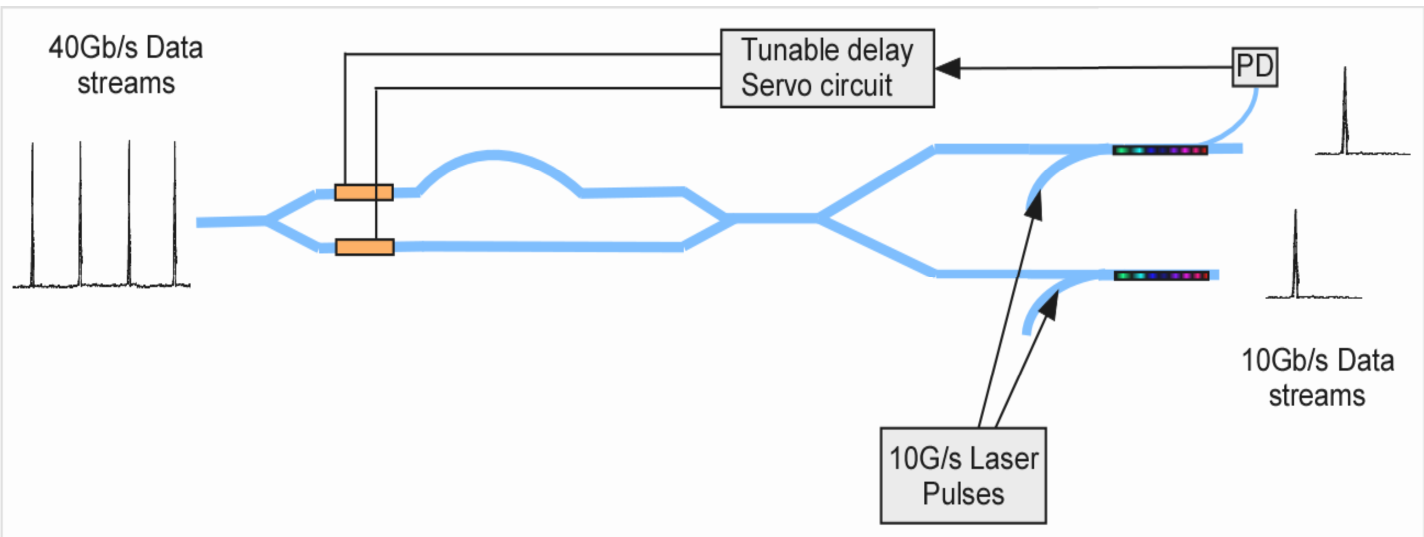
DeMux:



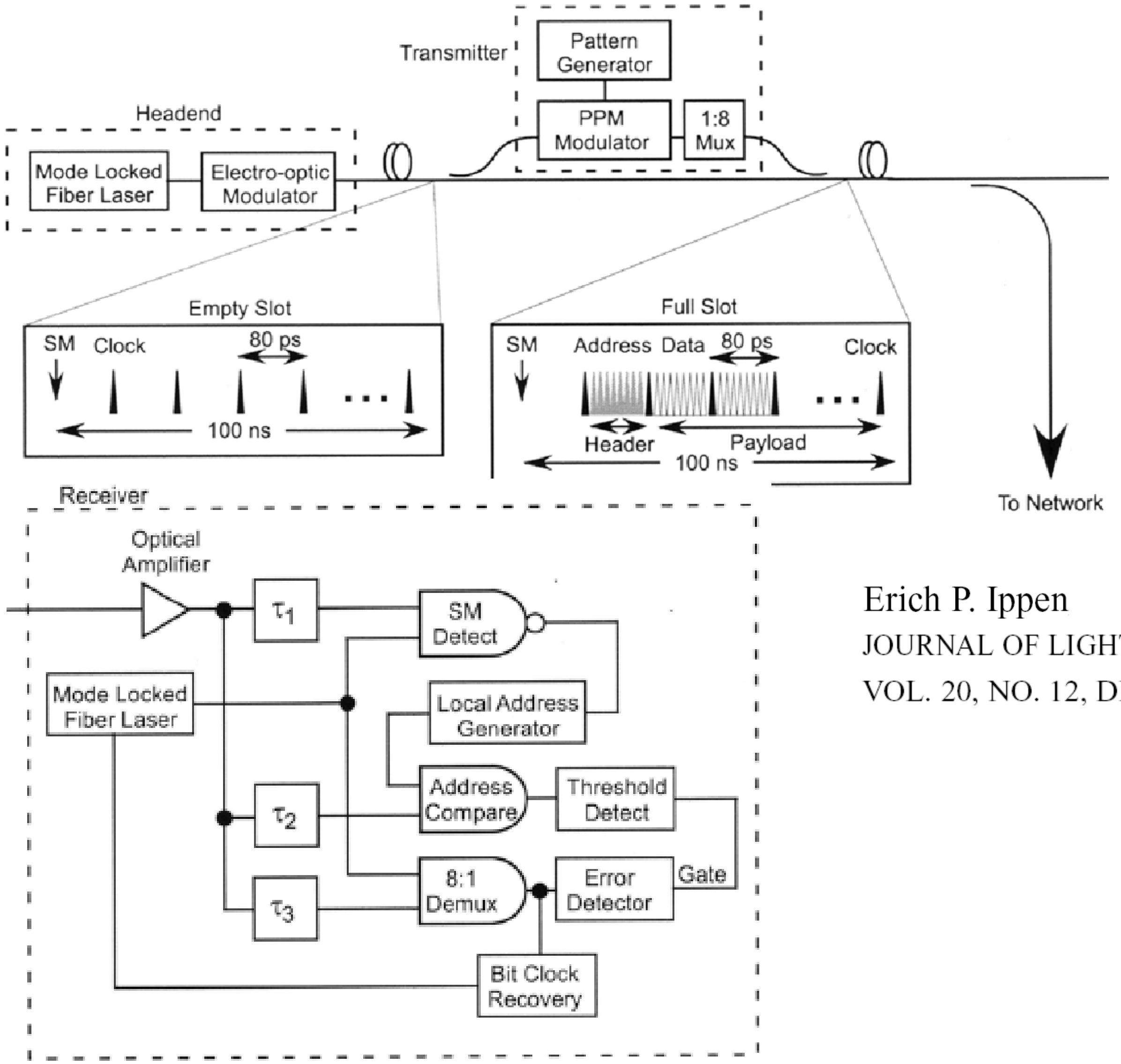
Architecture of 100Gb/s Transceiver Module

Re-timing and re-shaping:



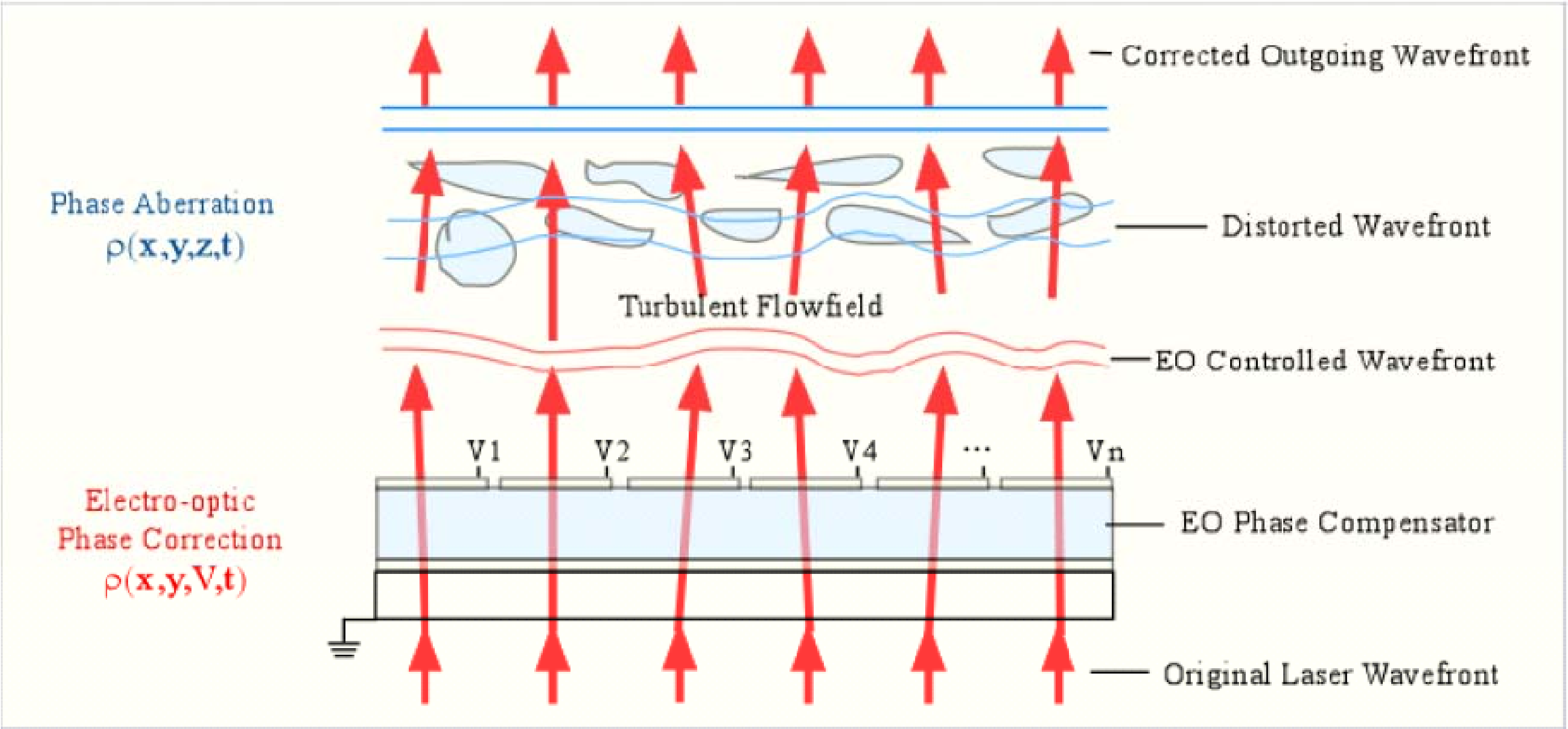


Other possible application – Optical Threshold Gates



Erich P. Ippen
JOURNAL OF LIGHTWAVE TECHNOLOGY,
VOL. 20, NO. 12, DECEMBER 2002

Optical phase corruption



2-D EO phase array