Empowered by Innovation NEC

InP modulator with linear-accelerator-type tiny in-line centipede electrode structure for directly driving with CMOS-IC

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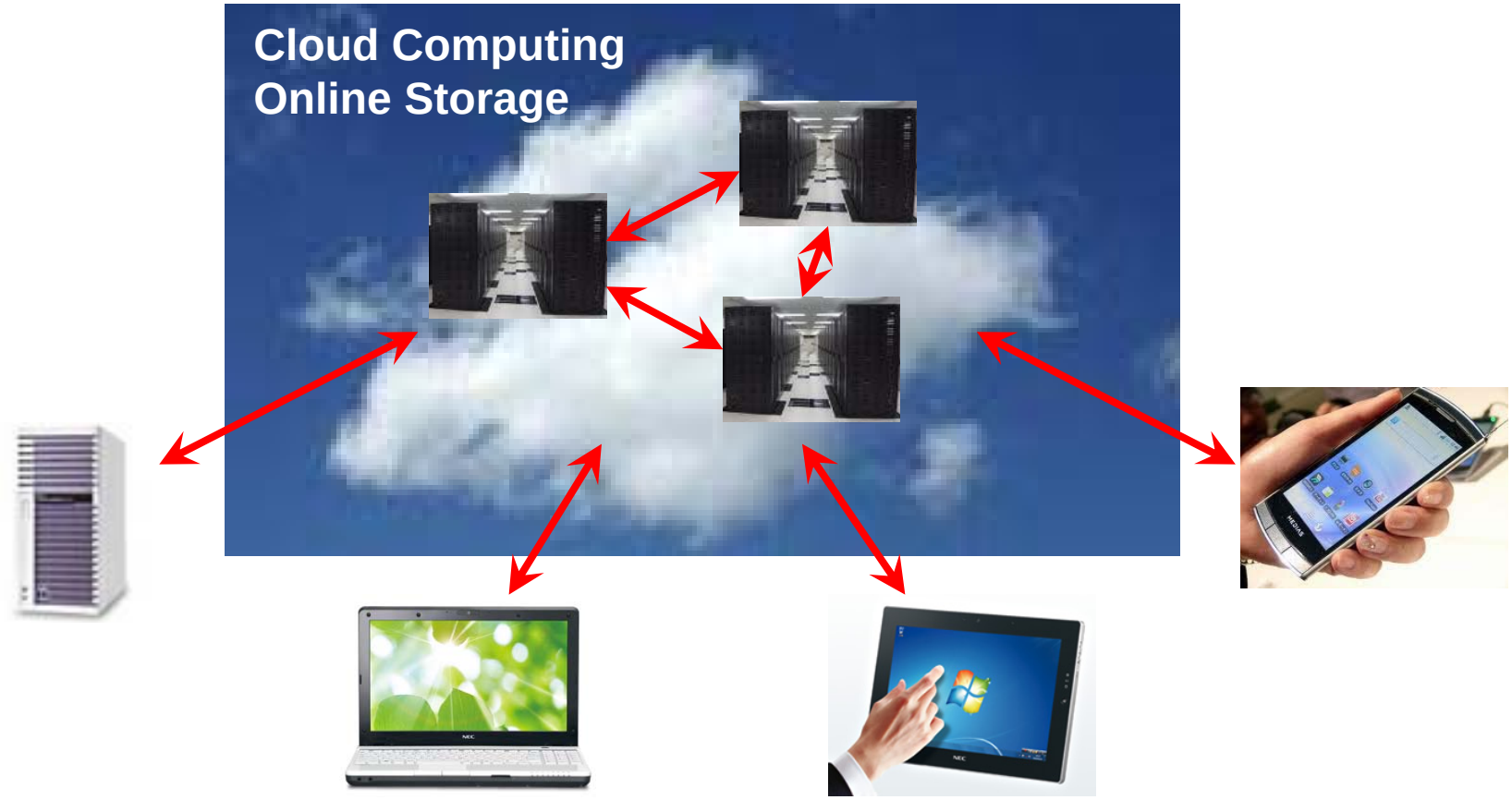
Background

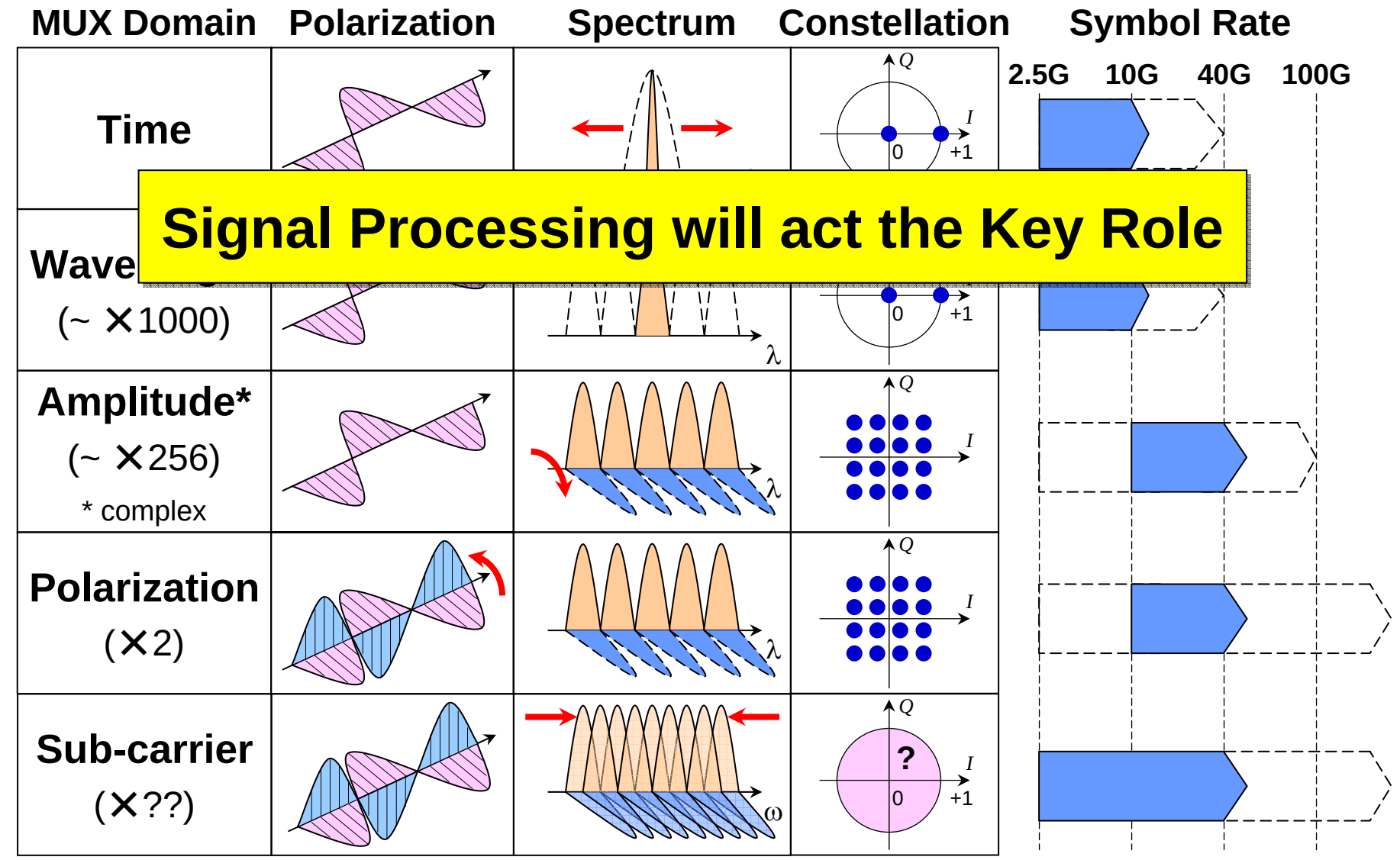


Everything will be connected ··· anytime, anywhere.

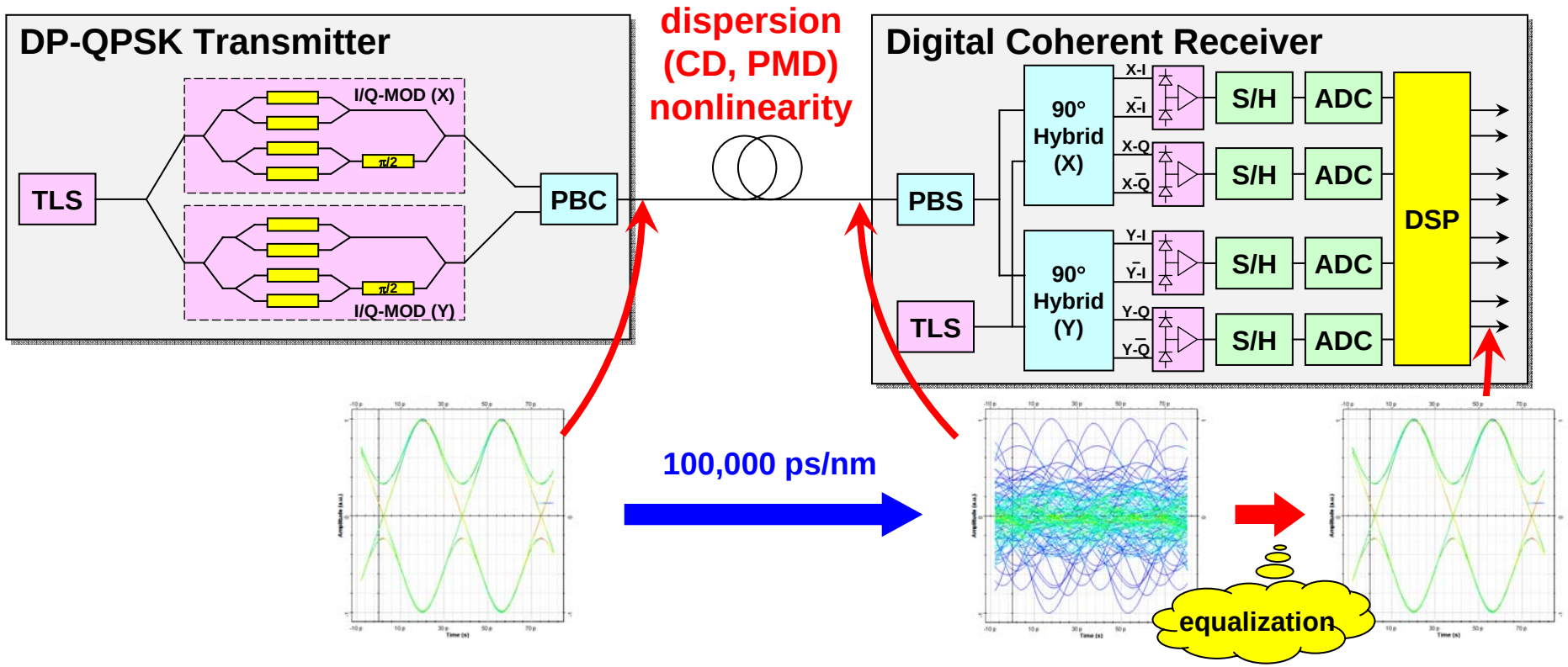
Key Issue

- **Scalability Scenario of Transmission Capacity**

Scalability Scenario of Transmission Capacity



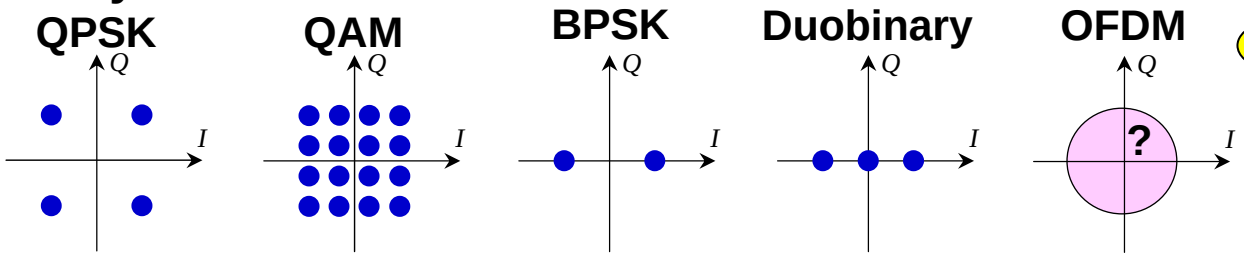
Digital Coherent System (Backbone)



DSP Application for Transmitter

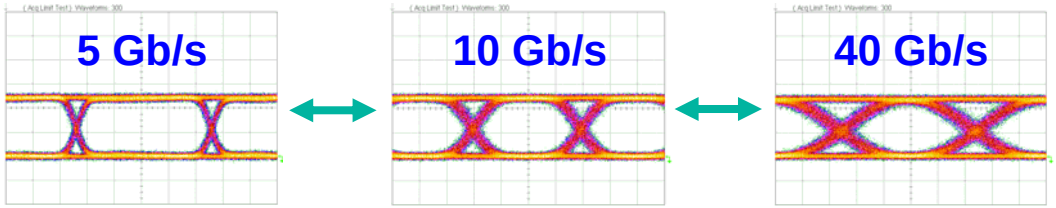
Adaptive Optical Transmitter

Arbitrary Modulation Format Generation



Spectral Efficiency
Grid-Free

Flexible Speed



Traffic Dependent
Performance Tuning

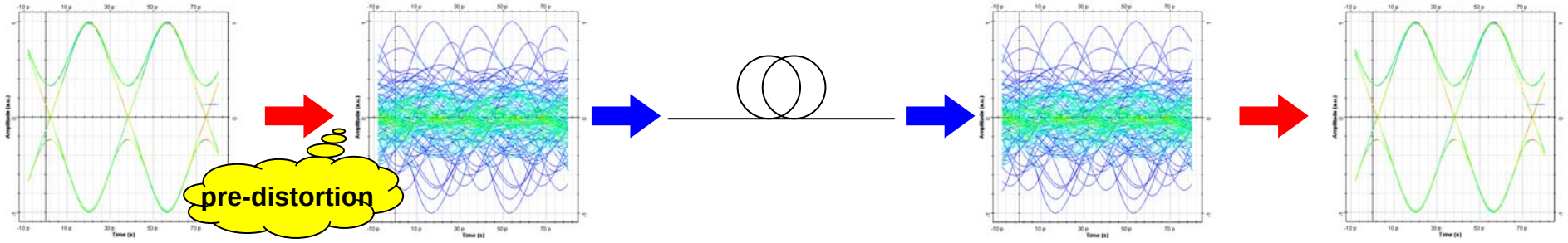
Lower Power
(dull)

Performance
(busy)

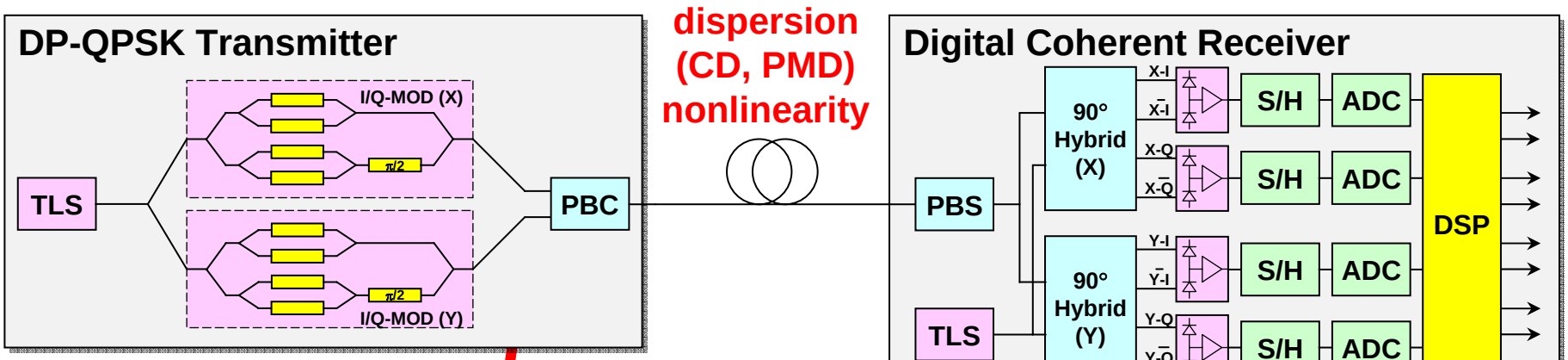
Longer Reach

Predistortion

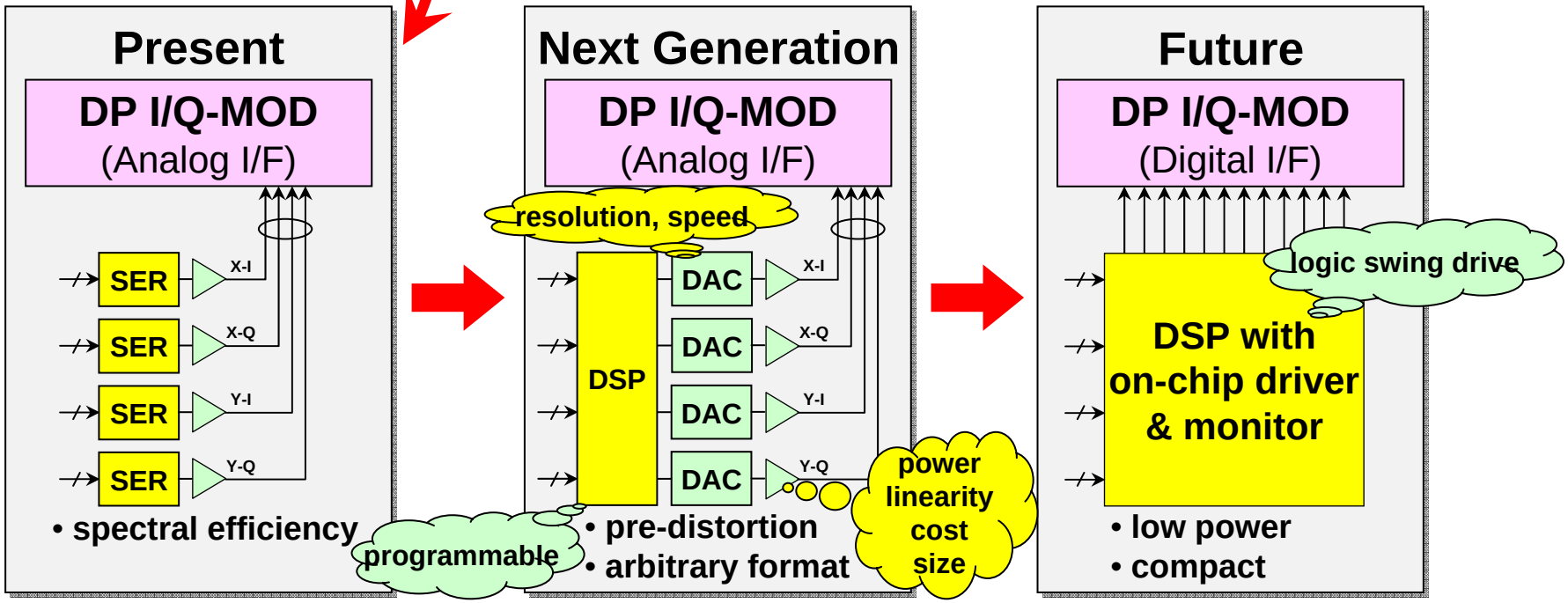
-100,000 ps/nm 100,000 ps/nm 100,000 ps/nm -100,000 ps/nm



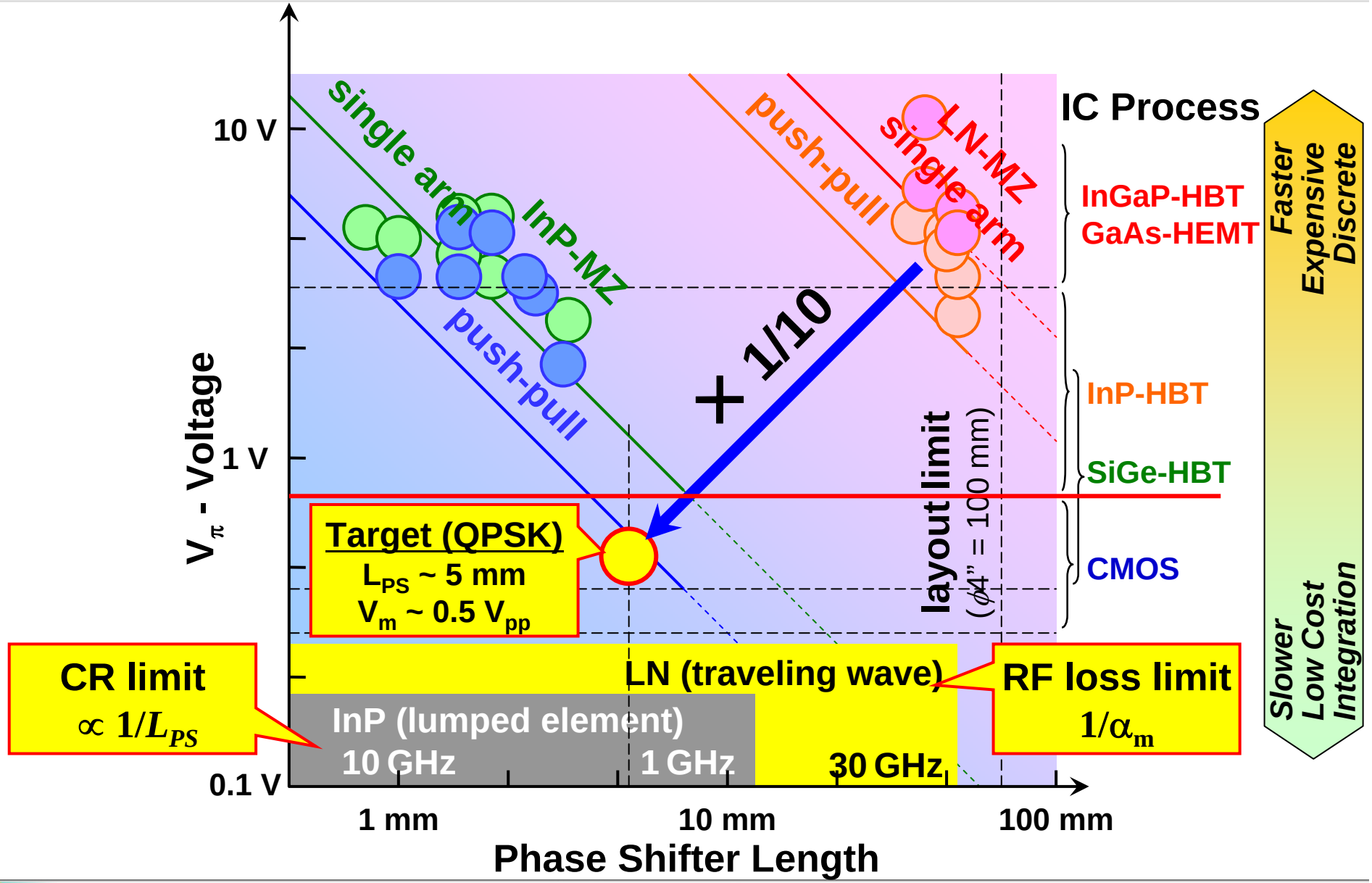
Motivation



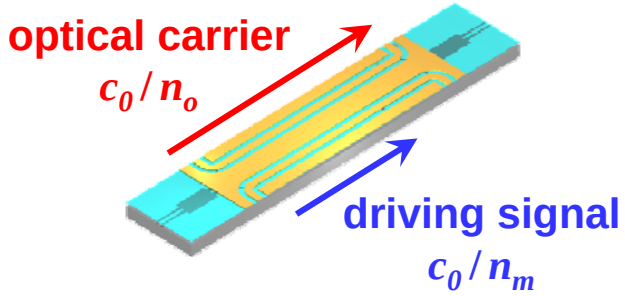
Evolution of OTx



MZ Modulator: $LiNbO_3$ vs InP



Traveling Wave Type Modulator



optical carrier $E_o(z,t) = E_{o0} e^{-\alpha_o z} \cos(\omega_o t - k_o z + \theta_o)$

driving signal $V_m(z,t) = V_{m0} e^{-\alpha_m z} \cos(\omega_m t - k_m z + \theta_m)$

$$V_m'(z',t) = V_{m0} e^{-\alpha_m z'} \cos\{\omega_m t - (k_m - k_o) z' + \theta_m\}$$

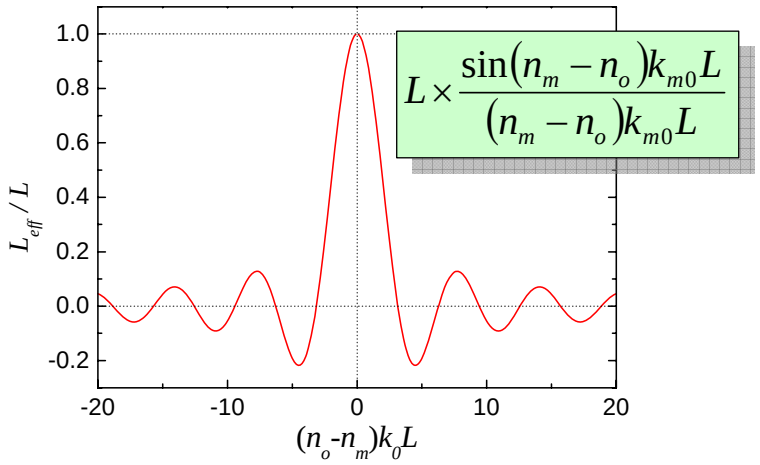
$$= V_{m0} e^{-\alpha_m z'} \cos\{\omega_m t - (n_m - n_o) k_{m0} z' + \theta_m - \theta_o\}$$

z' : relative coordinate

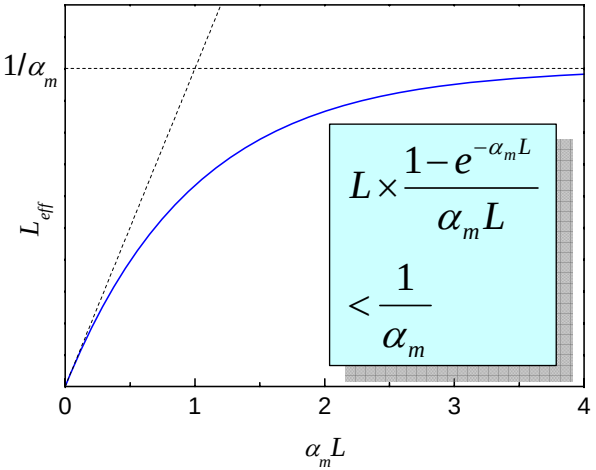
RF attenuation **velocity mismatch**

Effective Length ∝ 1/V

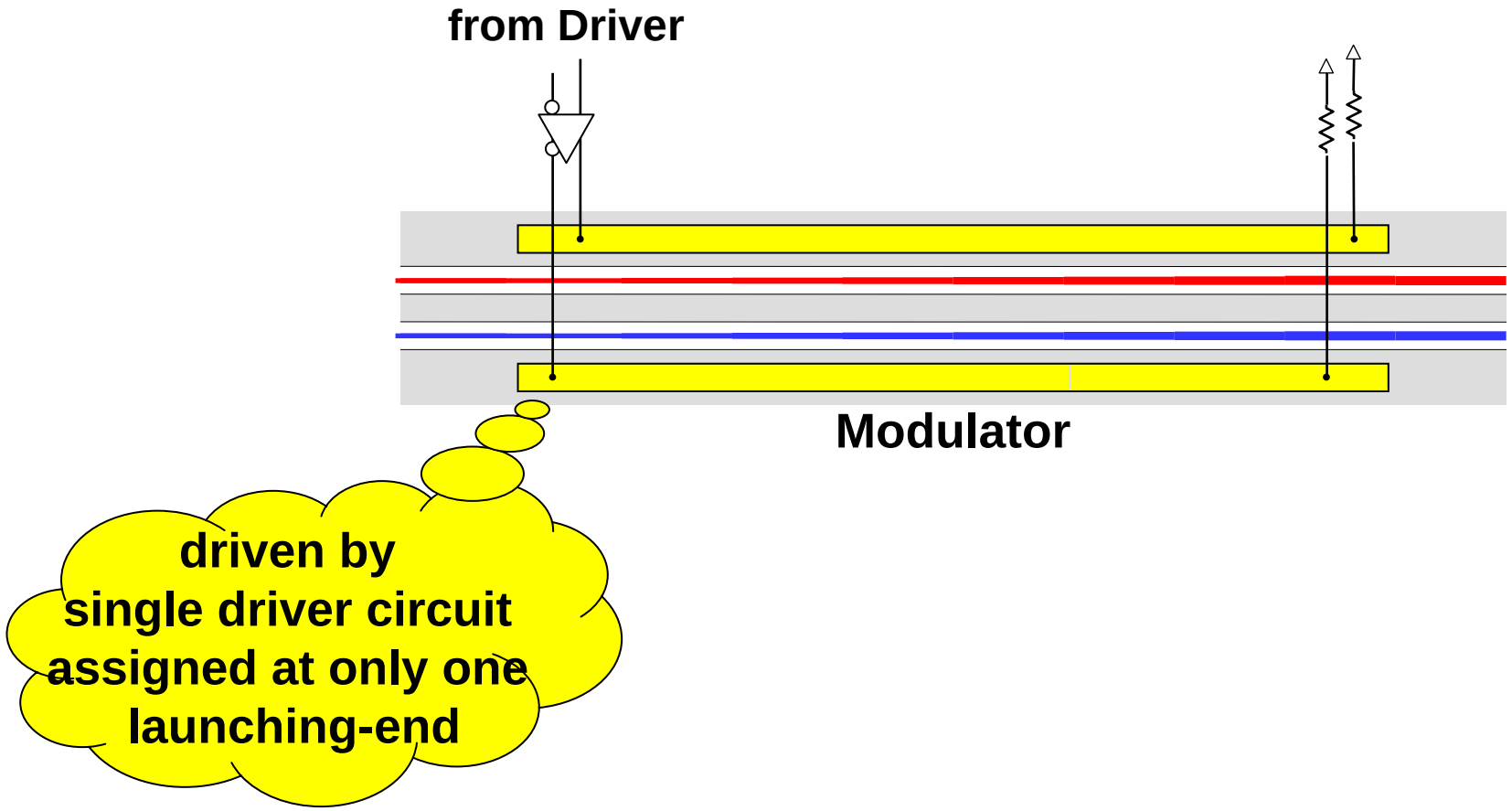
$\alpha_m = 0$



$n_m = n_o$



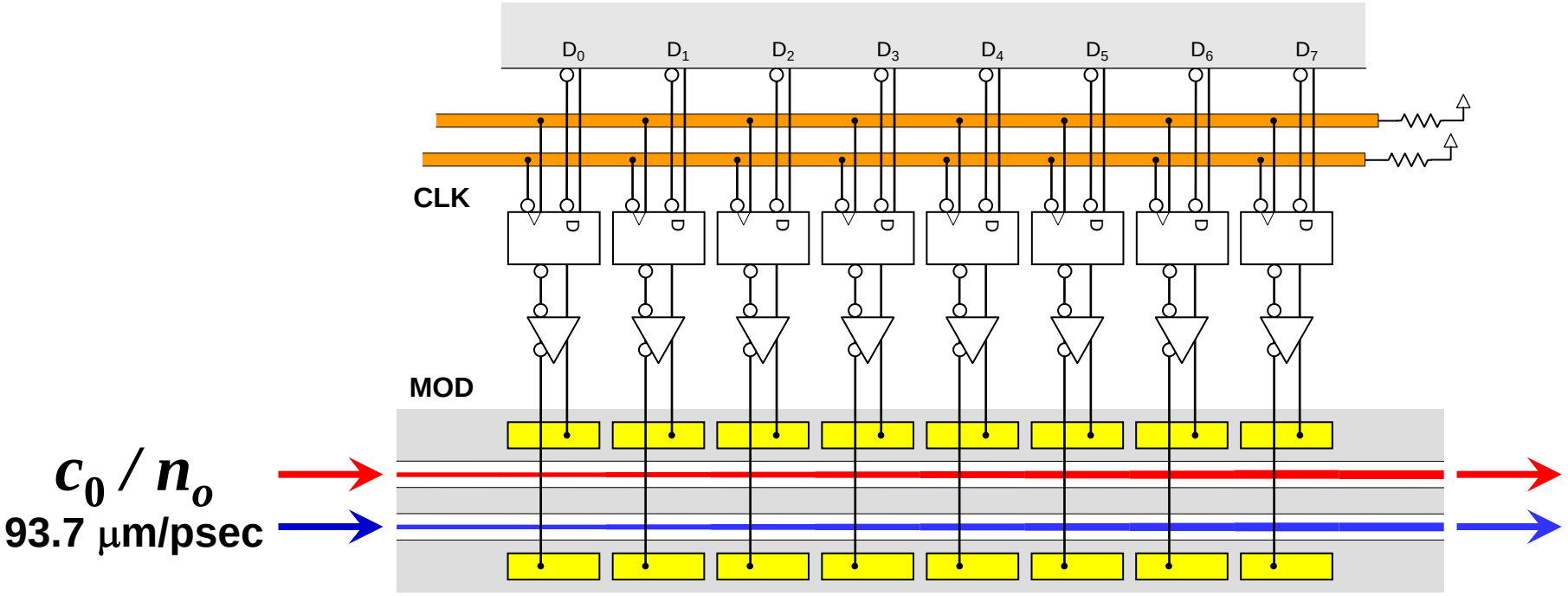
Origin of the TW Modulator's Problem



Our Proposal: Accelerator-like Electrodes

Particle Accelerator

Advantages of the Proposed Structure



Breaks $1/\alpha_m$ Limit
- $\Delta\phi \propto N$
- low electric field, reliable

Step Phase Shift
- DAC-like operation
- w/o DAC & linear AMP

Wide Bandwidth
- $C_{mod} \propto 1/N$

Logic Swing Drive
- sub 1-V_{pp} operation w/o Bias-T

Low Chirp
- suitable for I/Q modulator

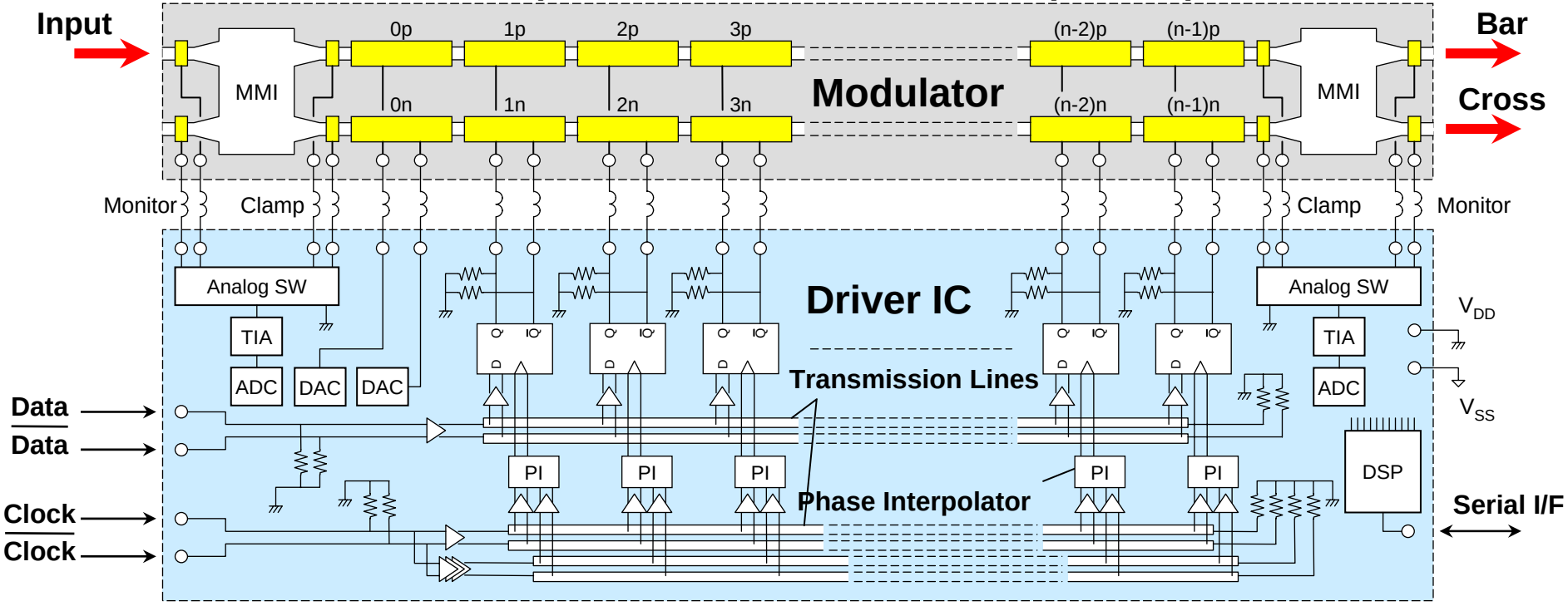
Digital-Conscious
- suitable for DSP control
- redundant
- high yield

Flexible WG Design
- free from TW's restriction
- even lumped element is applicable

Device Structure

InP Modulator (6 mm × 0.25 mm × 2set)

Driver IC (5 mm × 0.9 mm, 90-nm CMOS process)

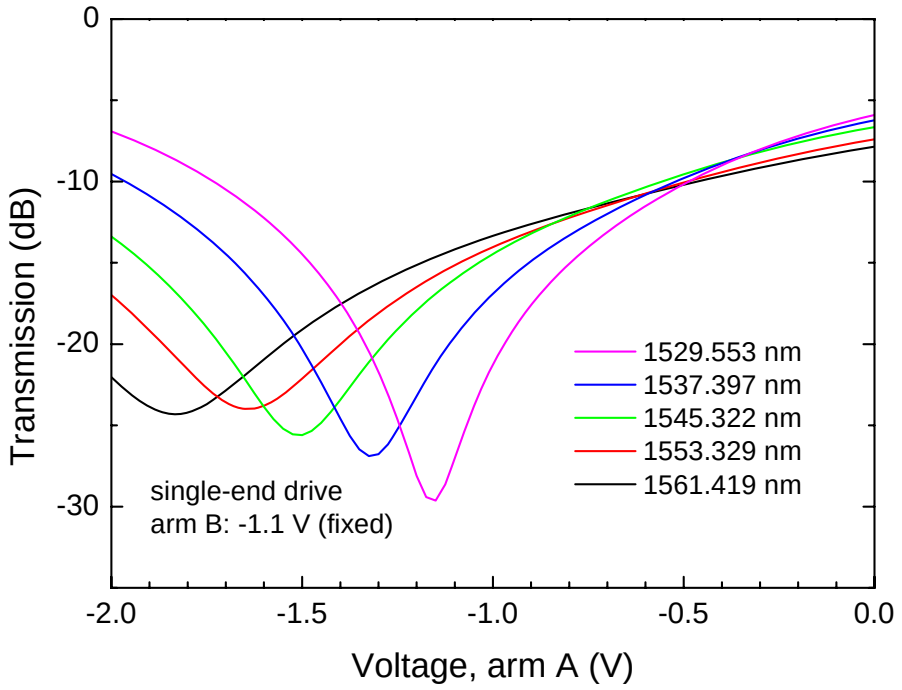


InP Mach-Zehnder Modulator

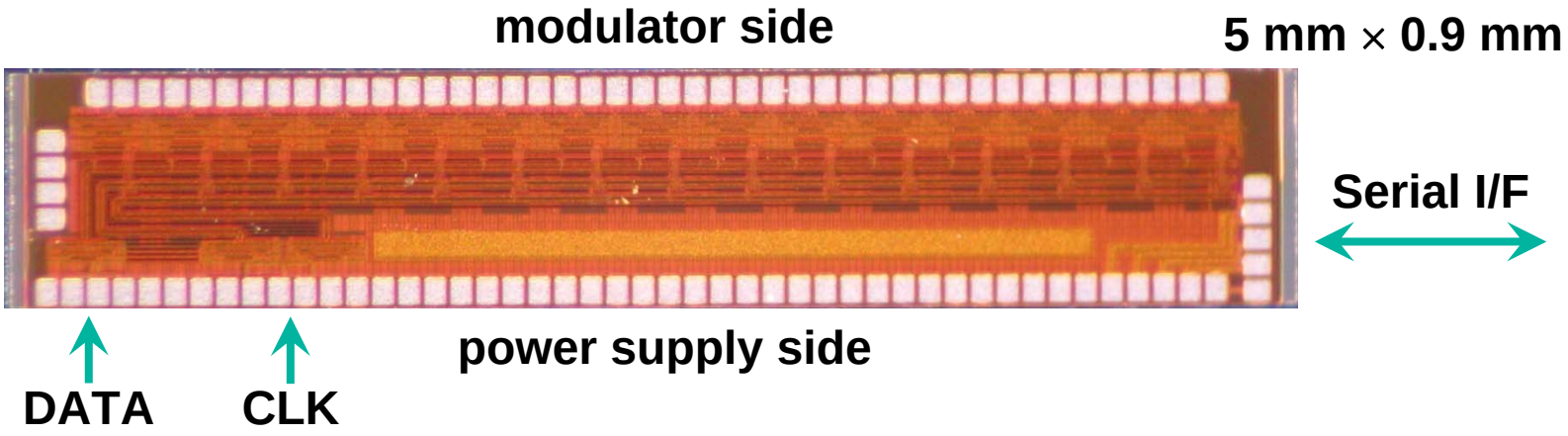
6 mm × 0.25 mm × 2 sets

- **Rib Waveguide Structure**
  - AlGaInAs/AlGaAs-MQW SCH
  - Single step MOVPE Growth
  - 2-step ICP-RIE
- **2 GI-MMI Couplers**
- **16 Phase Shifters / Arm**
  - modulation (15), phase adjust (1)
  - pad layout: G-S-S-G
  - 285 μm/section × 15 = 4,275 μm
- **Isolation: > 1MΩ**
  - Proton Implantation (15 μm)
- **Bandwidth: ~14 GHz@ -0.5 V**

Extinction Curve (single arm drive)

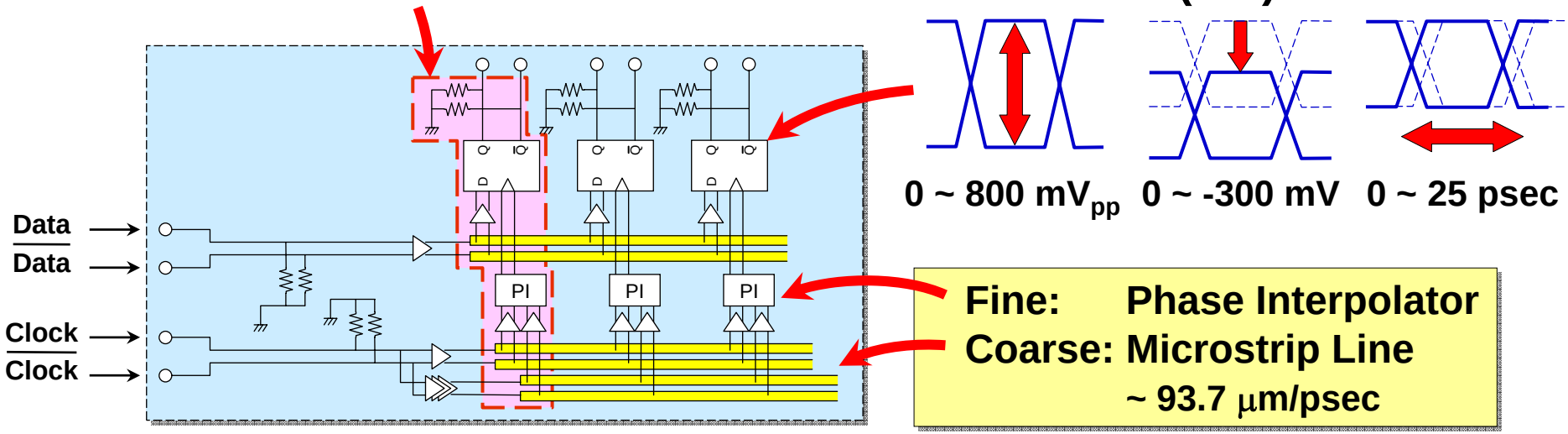


Modulator Driver IC

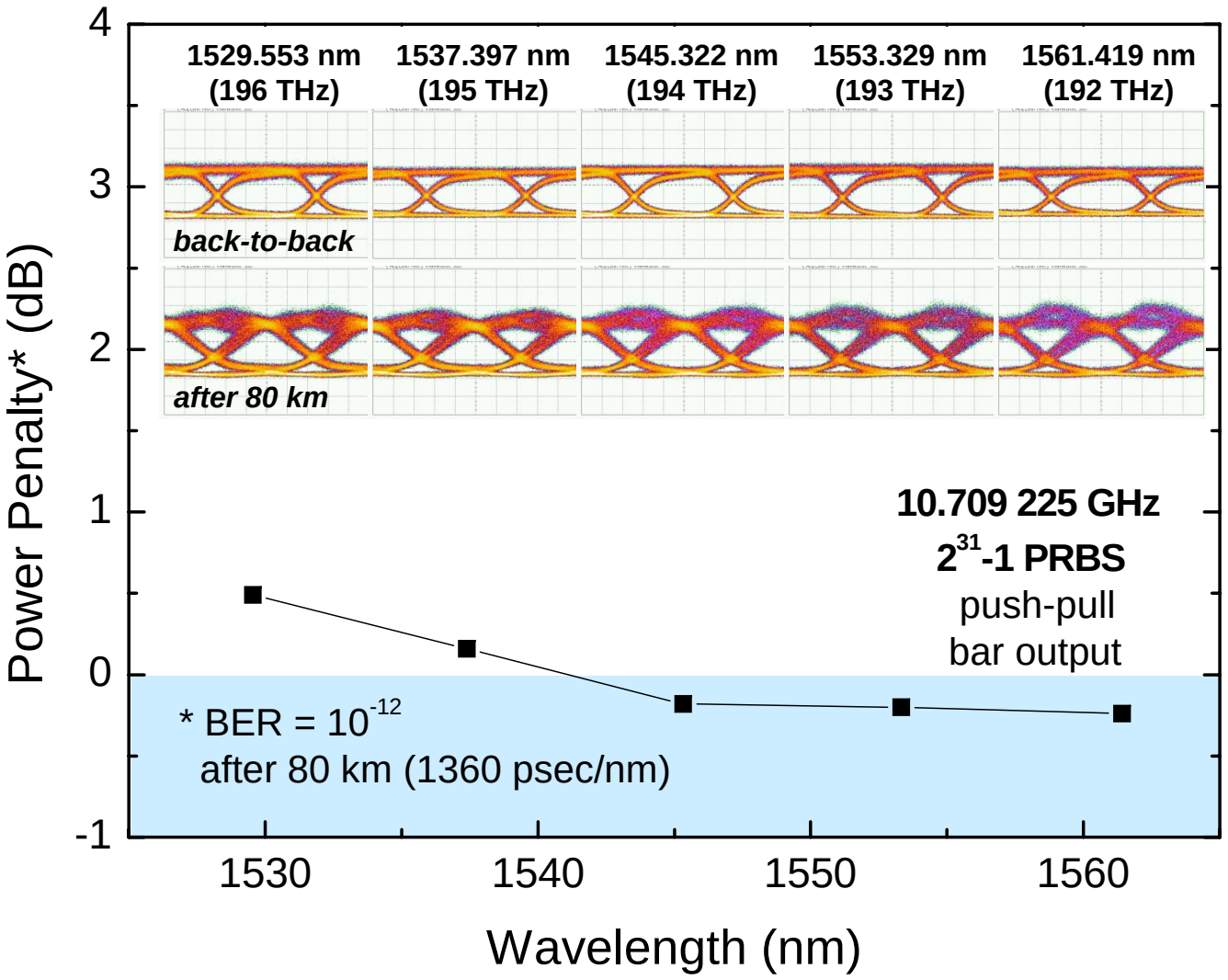


- 90-nm CMOS process
- Current Mode Logic
- 15 Sets of Sub-Driver Blocks

- Low Power: 980 mW@ -1.1 V
- Parameter Programmable with 5-bit DAC(×3) via Serial I/F



Transmission Characteristics



Summary

Accelerator-like Electrode Structure for InP-based Modulator and Logic IC as its Driver

- **Driven directly w/o Bias-T by Logic Gate**
  - L_{PS} can be elongated beyond $1/\alpha_m$ limit
- **Low Chirp**
  - ideally low $d\alpha/dn$ of AlGaInAs-MQW core under low $|\boldsymbol{E}|$
- **Digital Conscious**
  - step phase shift operation w/o DAC
- **Flexible in Waveguide Design**
  - even lumped element electrodes are applicable

Key Enabler for >100 Gb/s Adaptive Optical Transceivers for Digital Photonics Era

Future Work

- **I/Q Modulator Configuration**
- **High-Speed CMOS-IC Design (28~56Gb/s)**
- **Module & Assembly Technologies**
- **>100G DP-QPSK Demonstration**
- **Arbitrary Modulation Format Generation**
- **Standardization**