

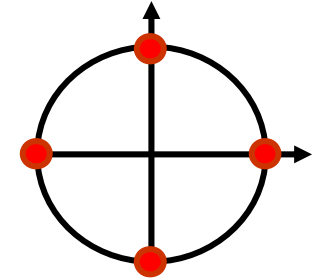
# High-speed 16-QAM for serial PMDs

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# Multi-level modulation formats

## 4QAM and 16QAM

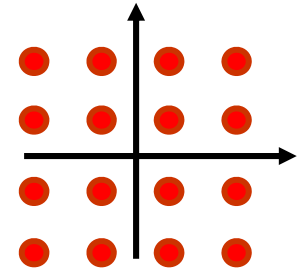


- (D)QPSK=4QAM

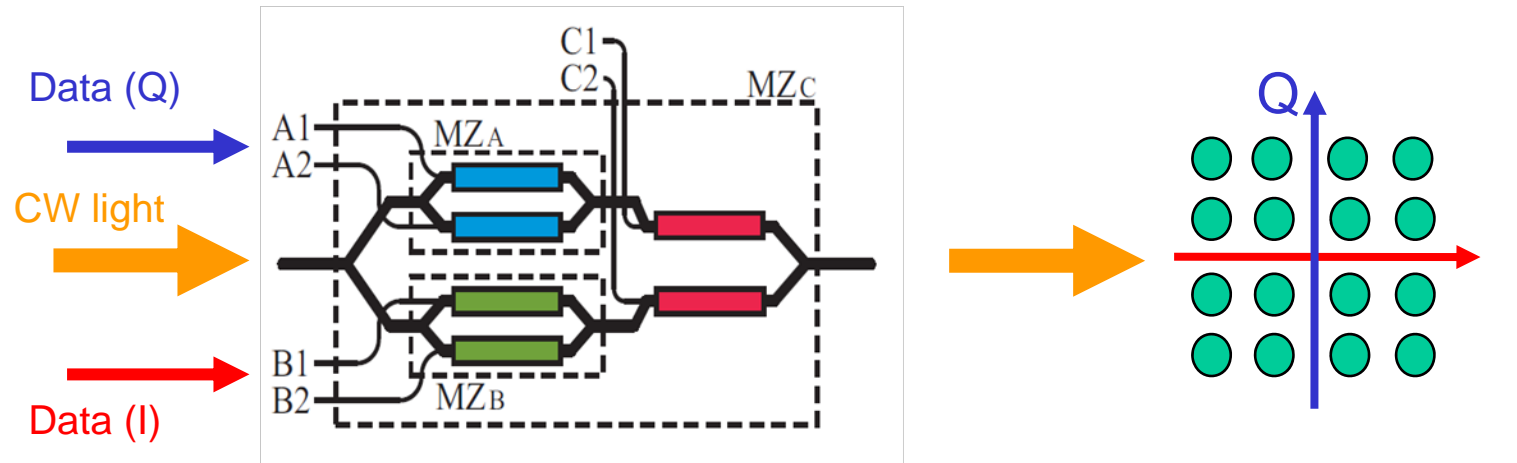
- 2bits/symbol (4bits/symbol with PDM)
- Modulator: IQ modulator (Dual parallel MZM, MZM+PM, etc.)
- Demodulator: Delay interferometer, Digital coherent, etc.
- Symbol rate: Over 50Gbaud was demonstrated.

- 16QAM

- 4bits/symbol (8bits/symbol with PDM)
- Modulator
  - IQ modulator with multi-level electric signals
  - Quad parallel MZM:QPMZM (T. Sakamoto et. al. ECOC 2007. PD2.8),
  - EAM-based integrated photonic circuits (C. R. Doerr et. al., OFC 2008, PDP20)
- Demodulator: Digital coherent, etc.
- Symbol rate: 12.5Gbaud was demonstrated.
  - Scalable to over 25Gbaud using high-speed LN-MZM technologies.

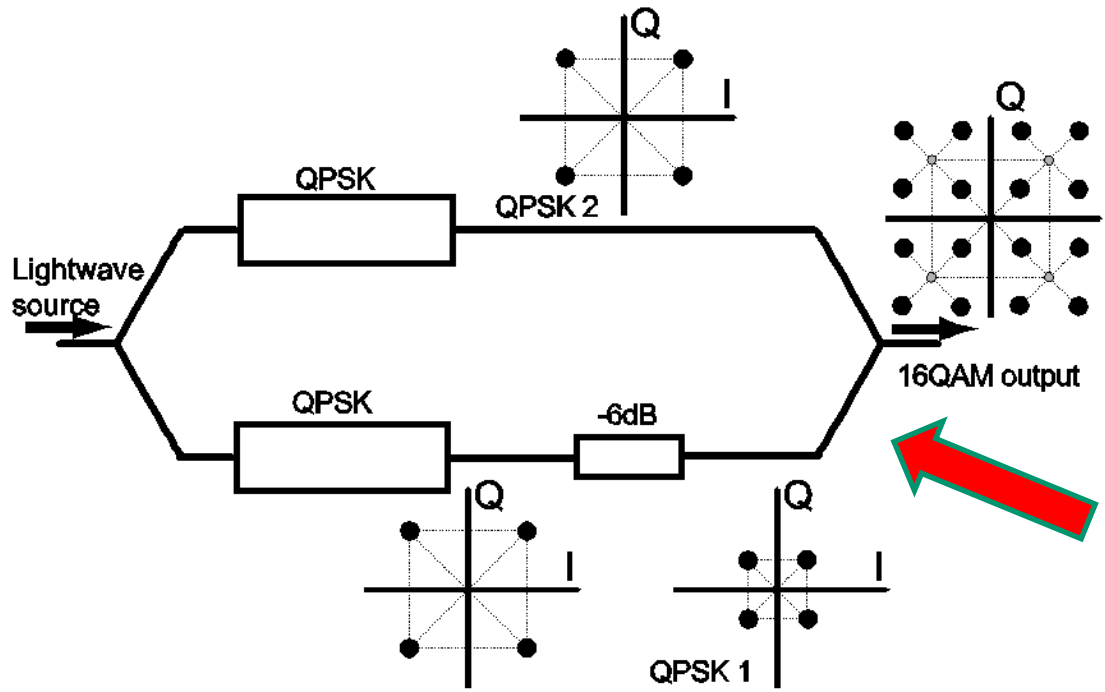


# QAM signal from multi-level electric signals

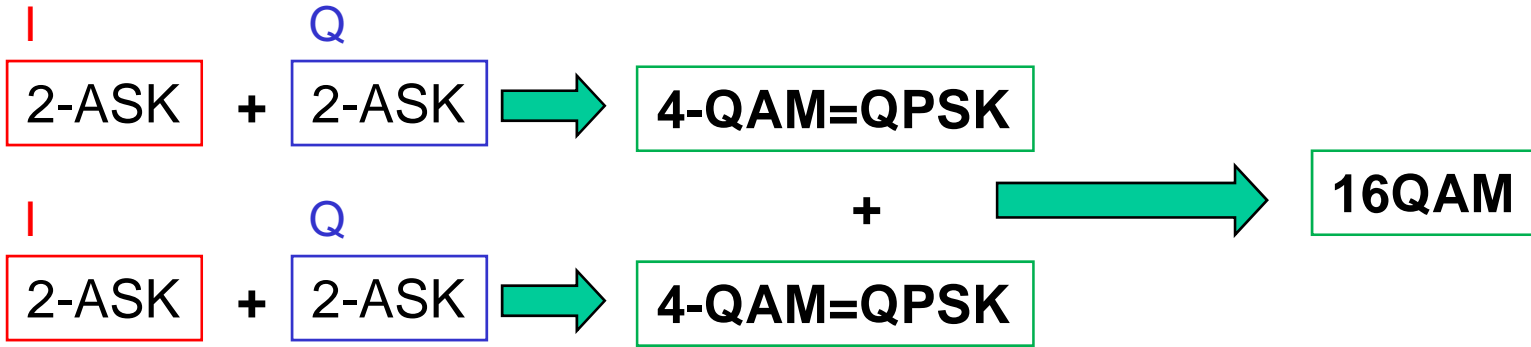


A pair of multi-level signals should be applied to the modulator. High-speed D/A conversion is needed for IQ modulation.

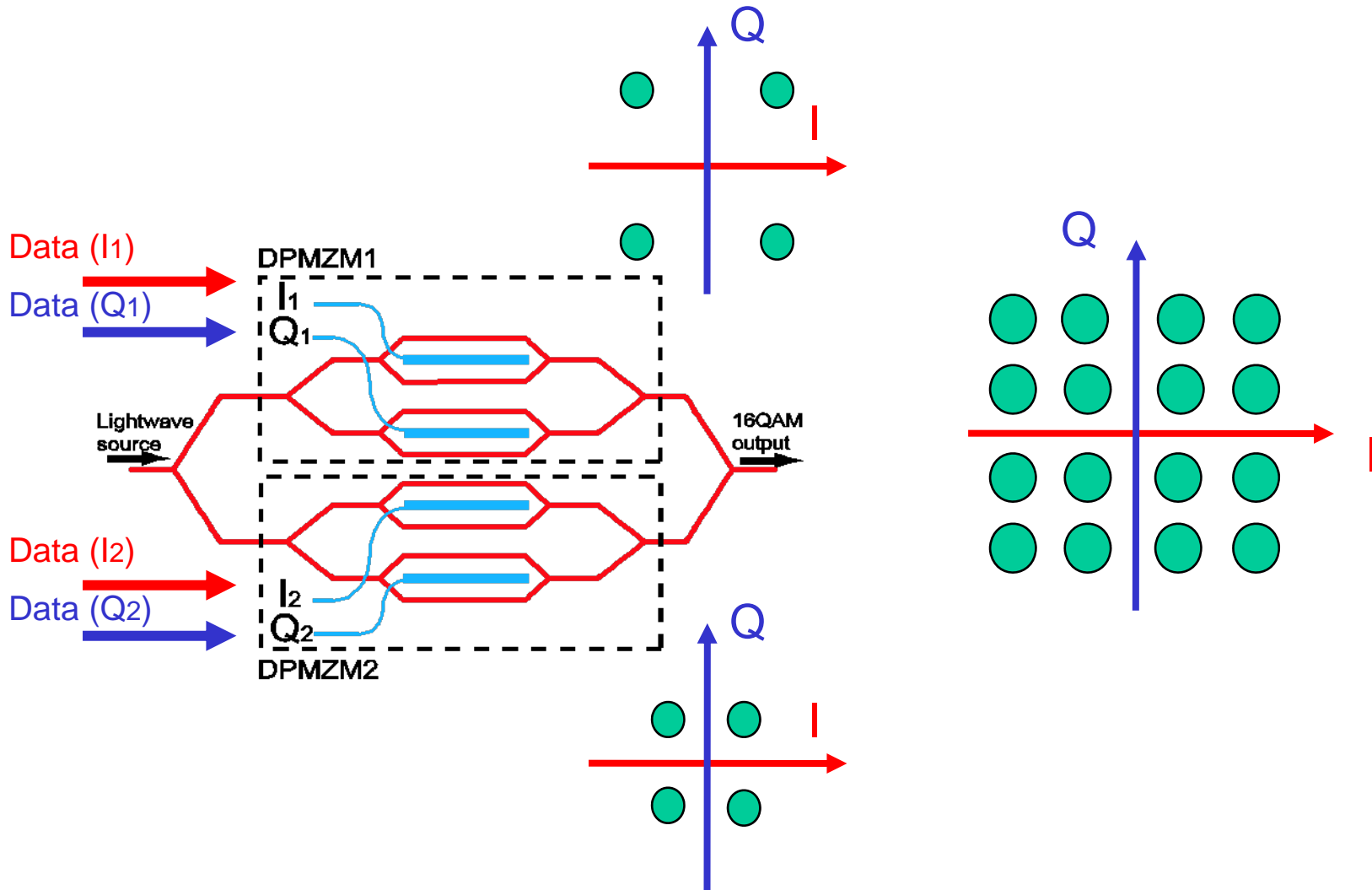
# QAM signal generation from binary signals



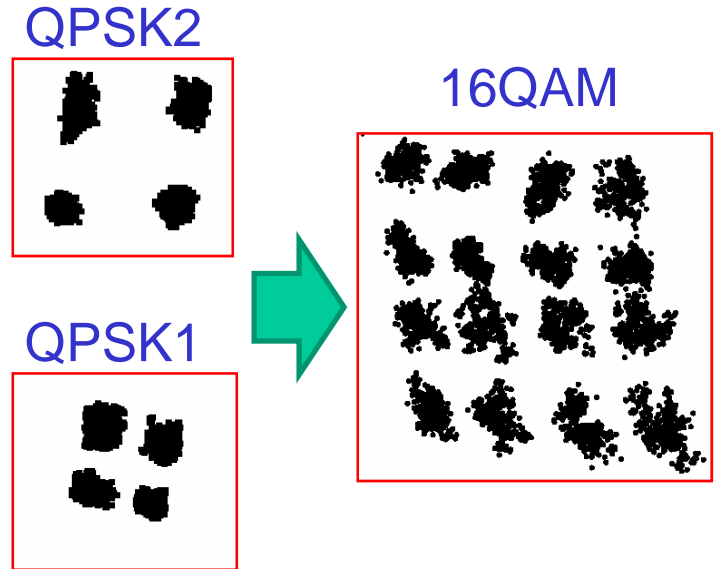
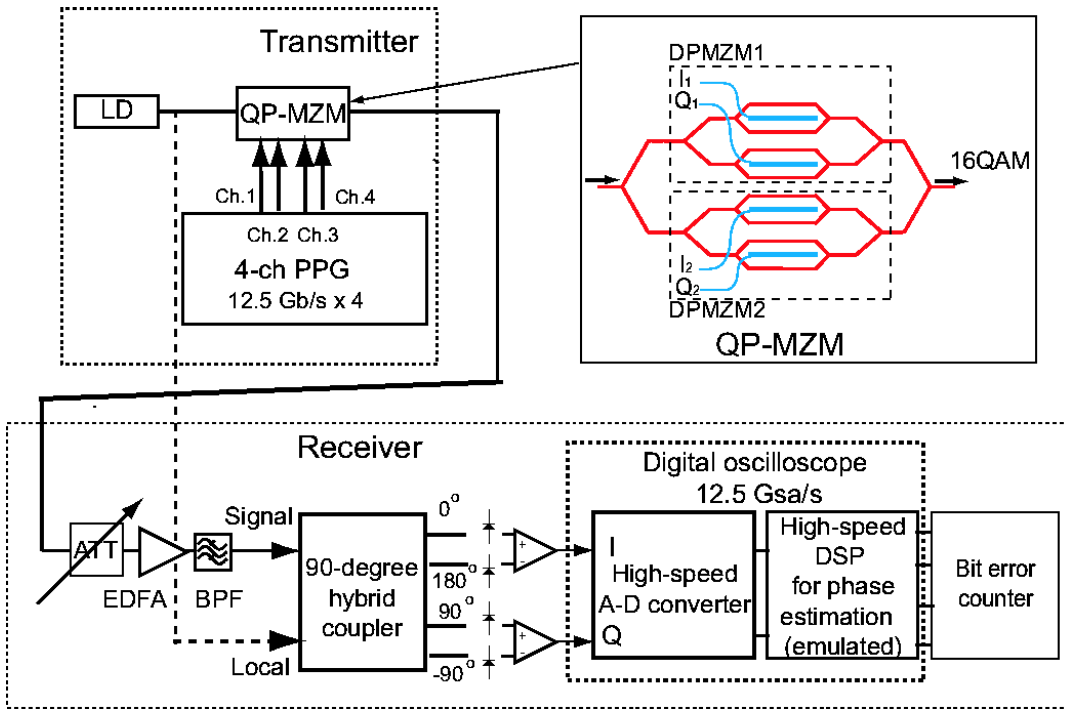
Ultra high-speed photonic vector DAC



# QAM signal from binary signals



# QPMZM for 16QAM



Ultra high-speed  
photonic vector DAC

50Gb/s 16QAM (12.5Gbaud)  
from 4 binary data streams

ECOC 2007  
Post deadline 2.8

# 100Gbps system using 16QAM

50Gbps (=12.5Gbaud x4)

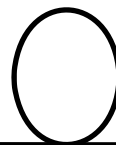
12.5Gbaud  
16QAM Tx

12.5Gbaud  
16QAM Tx

50Gbps (=12.5Gbaud x4)

100Gbps (=50Gbps x2)

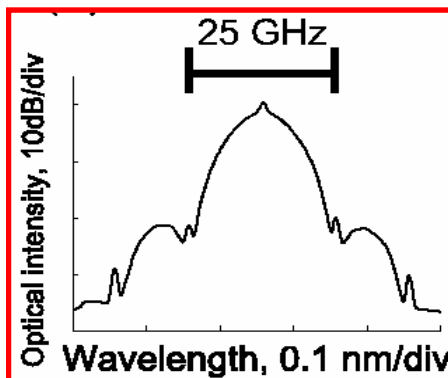
Pol. MUX



12.5Gbaud Digital  
Coherent Rx

Photonic LO

Digital coherent  
receiver



Experimental results on a single polarization 50Gbps QAM.

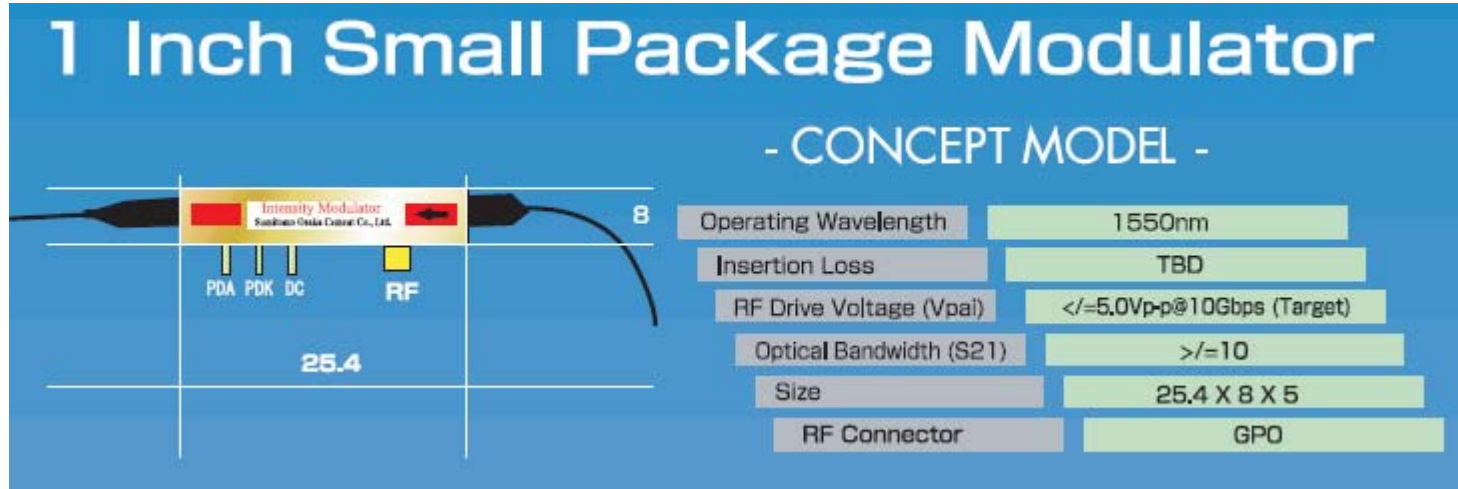


Integrated QP-MZM

IL 9.8dB

BW 12.5GHz(3dB) 25GHz(6dB)

# Small-size LN technology



from Sumitomo Osaka Cement

Typical size of conventional 10G MZM: 70x10x7

1-inch small package MZM: 25.4x8x5

 -80%



# Summary

- High-speed integrated modulators for 16-QAM can be realized in LN-MZM.
- Small-size LN technology can provide compact 16-QAM modulators.
- Digital coherent technology can demodulate high-speed QAM signals.
- 16QAM is one of candidate for 100G serial PMDs.
  - 14Gbaud with PDM
  - 28Gbaud without PDM