ITU-T Kaleidoscope Conference Innovations in NGN

Advanced Optical Modulators with Hybrid Configuration of Silica-based PLC and $LiNbO_3$ Phase-Shifter Array for Ultra-High-Speed Transport Networks

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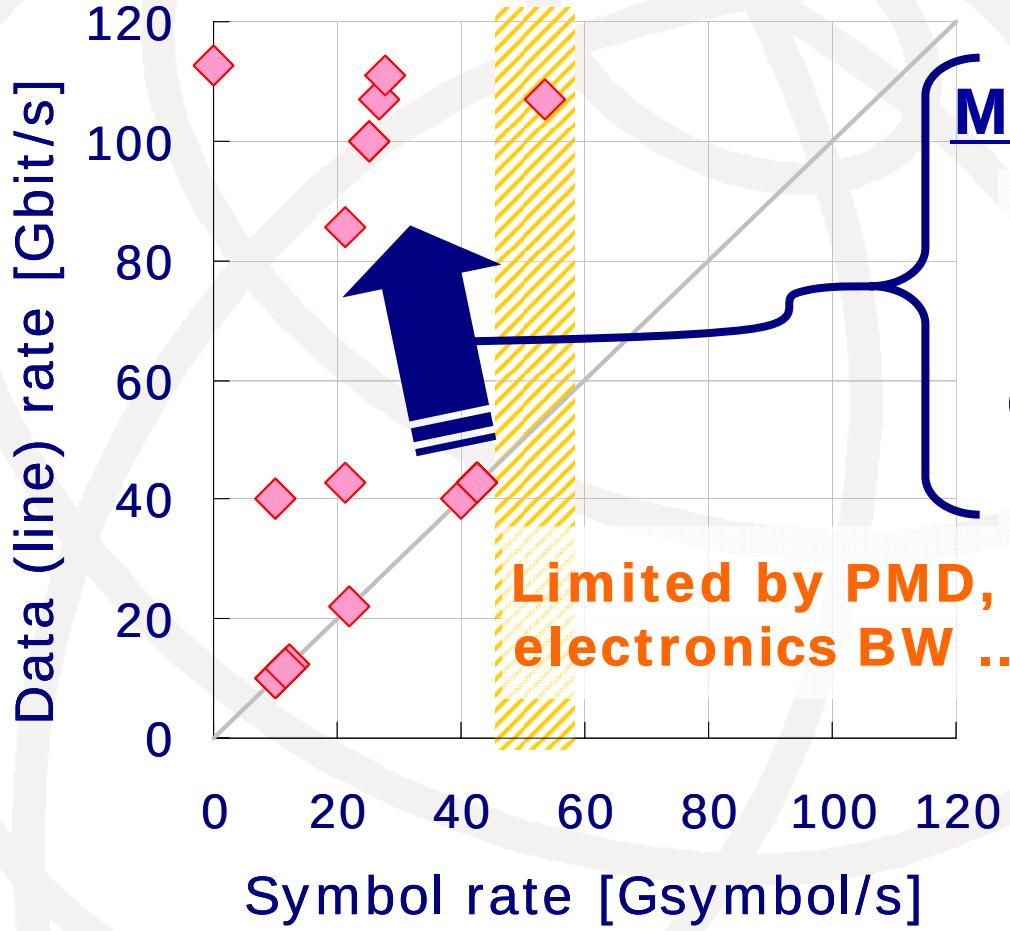
Outline

- Introduction
  - Concept of PLC-LN hybrid
- PLC-LN hybrid modulators
  - DQPSK modulator
  - 2-subcarrier-OFDM-DQPSK modulator
- Conclusion

Trends in Transmission Schemes for 100G/λ Transport

Reported transmission experiments
(Total capacity >1 Tb/s, distance >1,000 km)



Multiple-bits/symbol

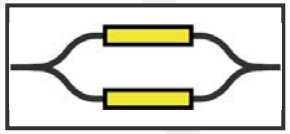
Multilevel mod.
(DQPSK, QAM ...)

Carrier MUX
(OFDM, PDM ...)

Complex Tx (& Rx) **required**

$LiNbO_3$ (LN) Modulator Integration

Single MZM



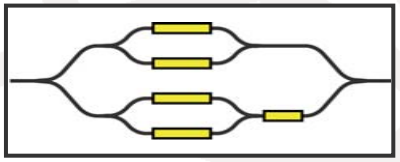
OOK

DB

DPSK

…

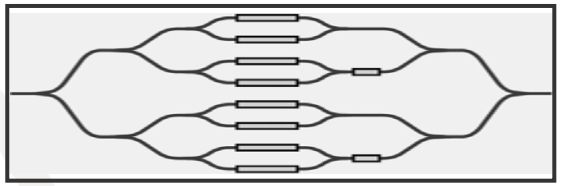
Nested Dual MZM



DQPSK

…

Further integration?

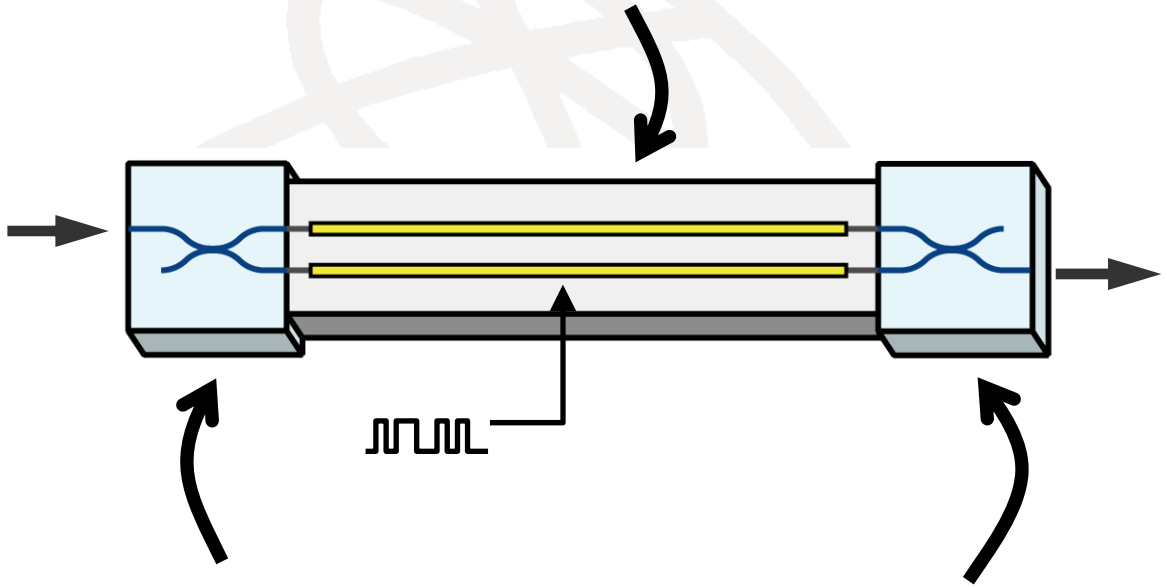


Obstacle:

Chip size > wafer (4")

Concept of PLC-LN Hybrid Modulator

LN: Simple high-speed modulators



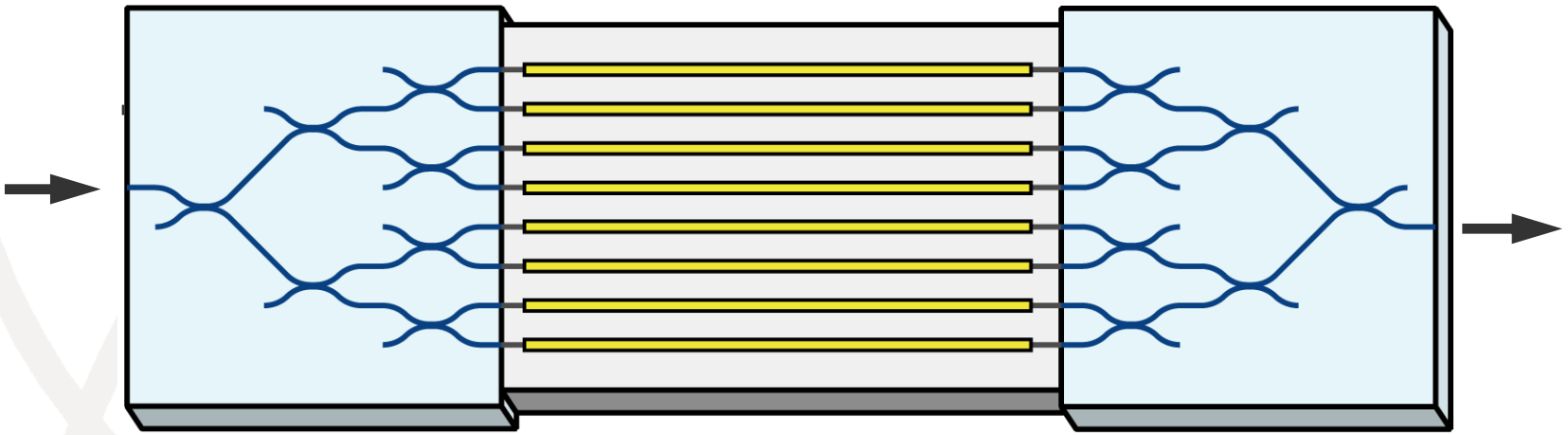
Silica PLC: Complex low-loss circuits

Concept of PLC-LN Hybrid Modulator

4 bit/symbol: 2-carrier DQPSK, 16 QAM…

2 bit/symbol: DQPSK …

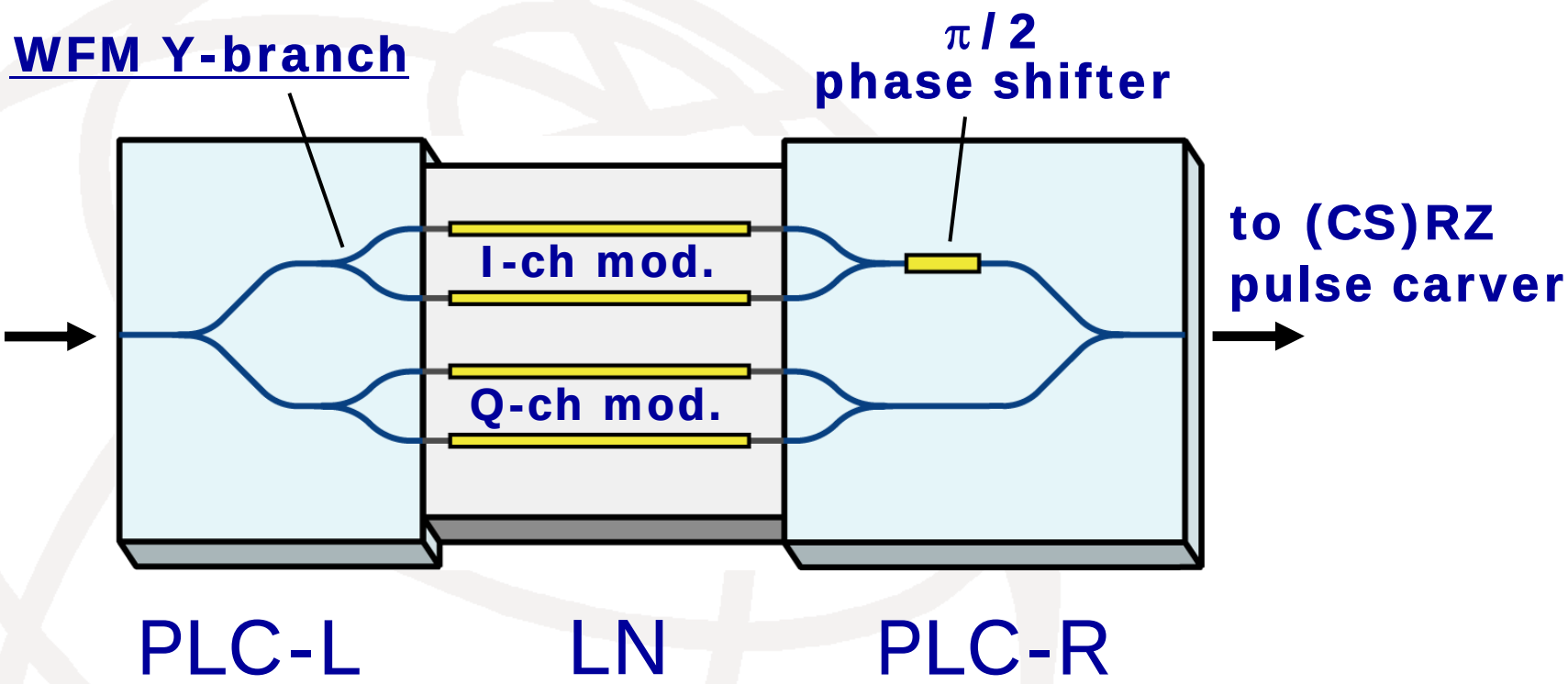
1 bit/symbol: OOK, DPSK…



Large-scale integration with low loss & practical chip size

DQPSK Modulator

Modulator Circuit

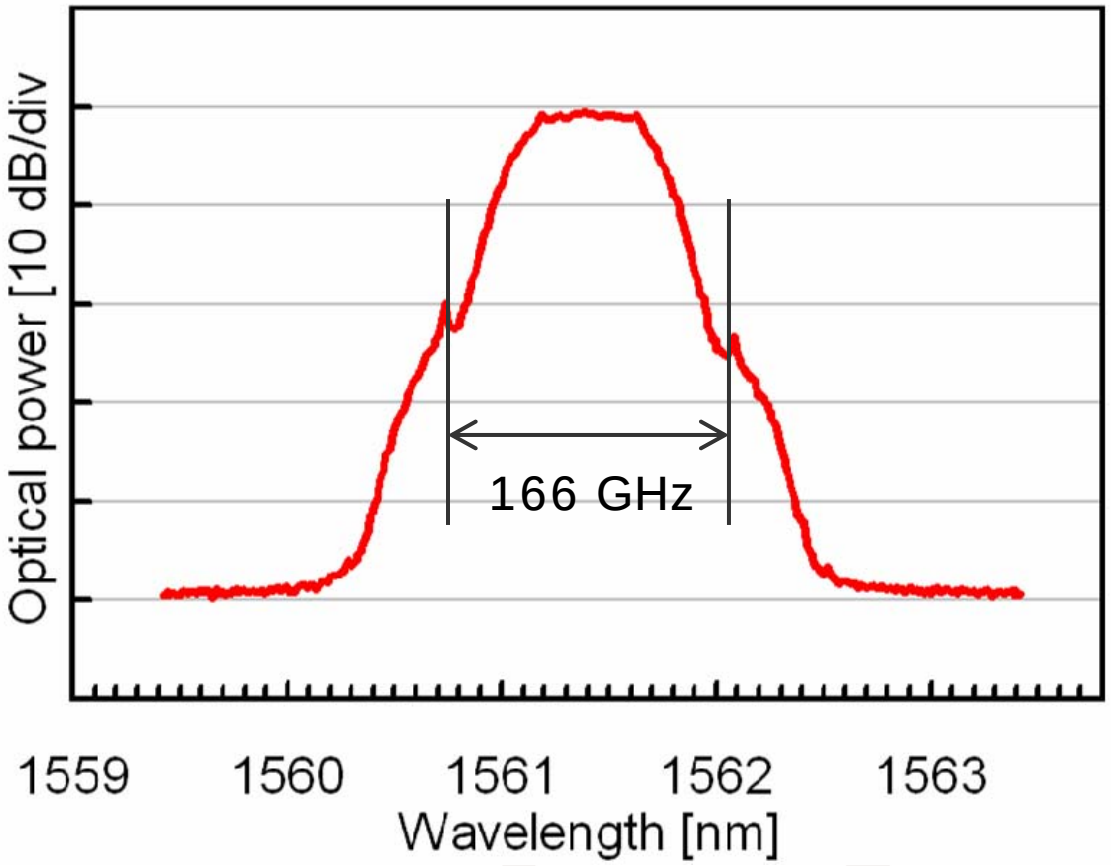


Module insertion loss: 6.5 dB

T. Yamada et al., IPNRA2007, ITuC2

Y. Sakamaki et al., Electron. Lett., vol. 43, no. 4, p. 217, 2007.

CSRZ-DQPSK (111G) Signal Spectrum

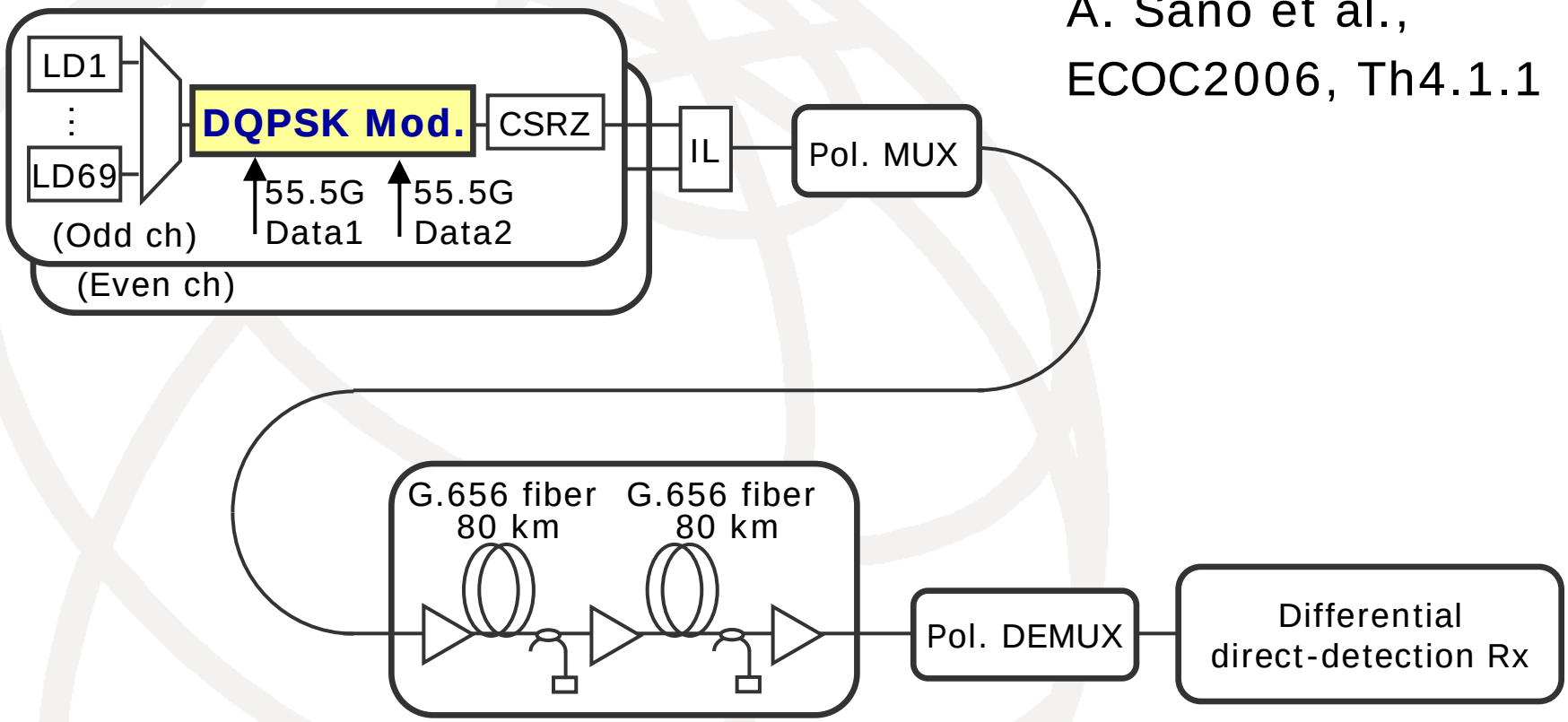


111 Gb/s with 166-GHz bandwidth

Setup for Transmission Experiment

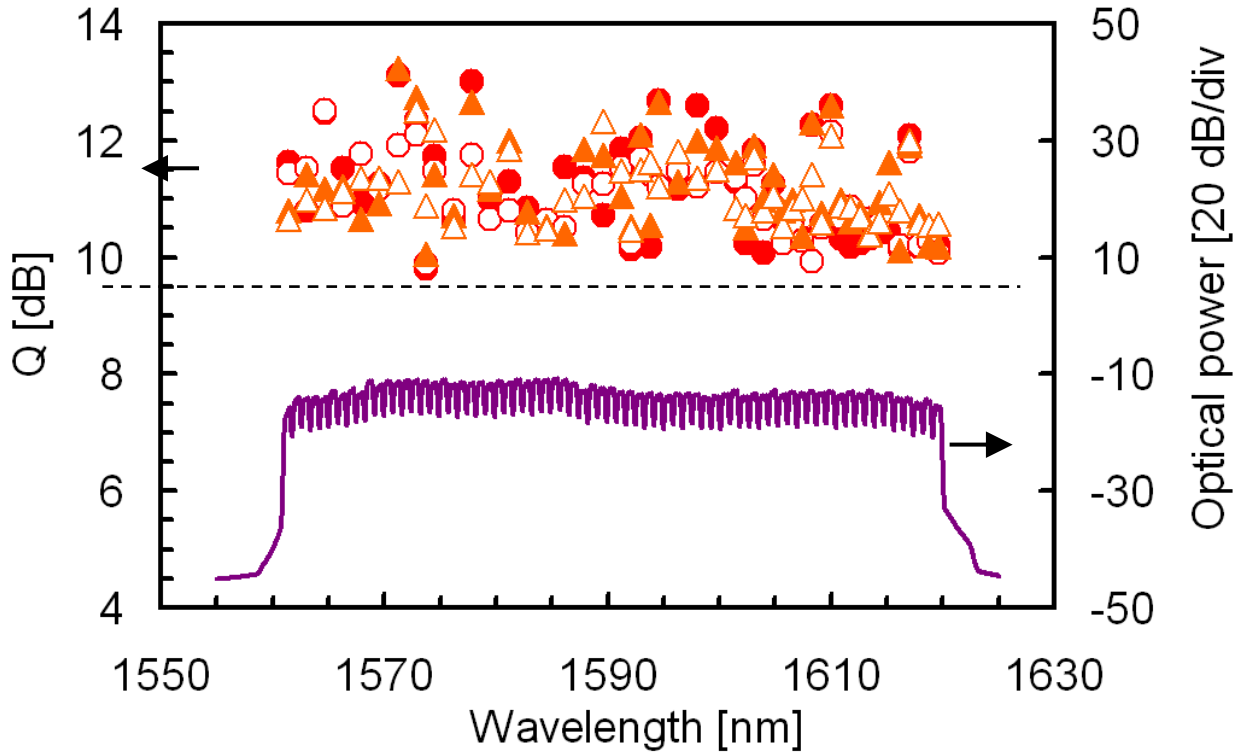
111 Gb/s x 70λ Tx

A. Sano et al.,
ECOC2006, Th4.1.1



160-km transmission line
(w/o band-filtering nodes)

Q-factor & Received Optical Spectra

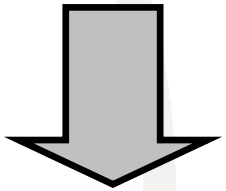


Successful transmission of 14 Tb/s (111 Gb/s x 2 pol. x 70λ) over 160 km

Remaining Challenges

Greater distance (160 km → >1,000 km)

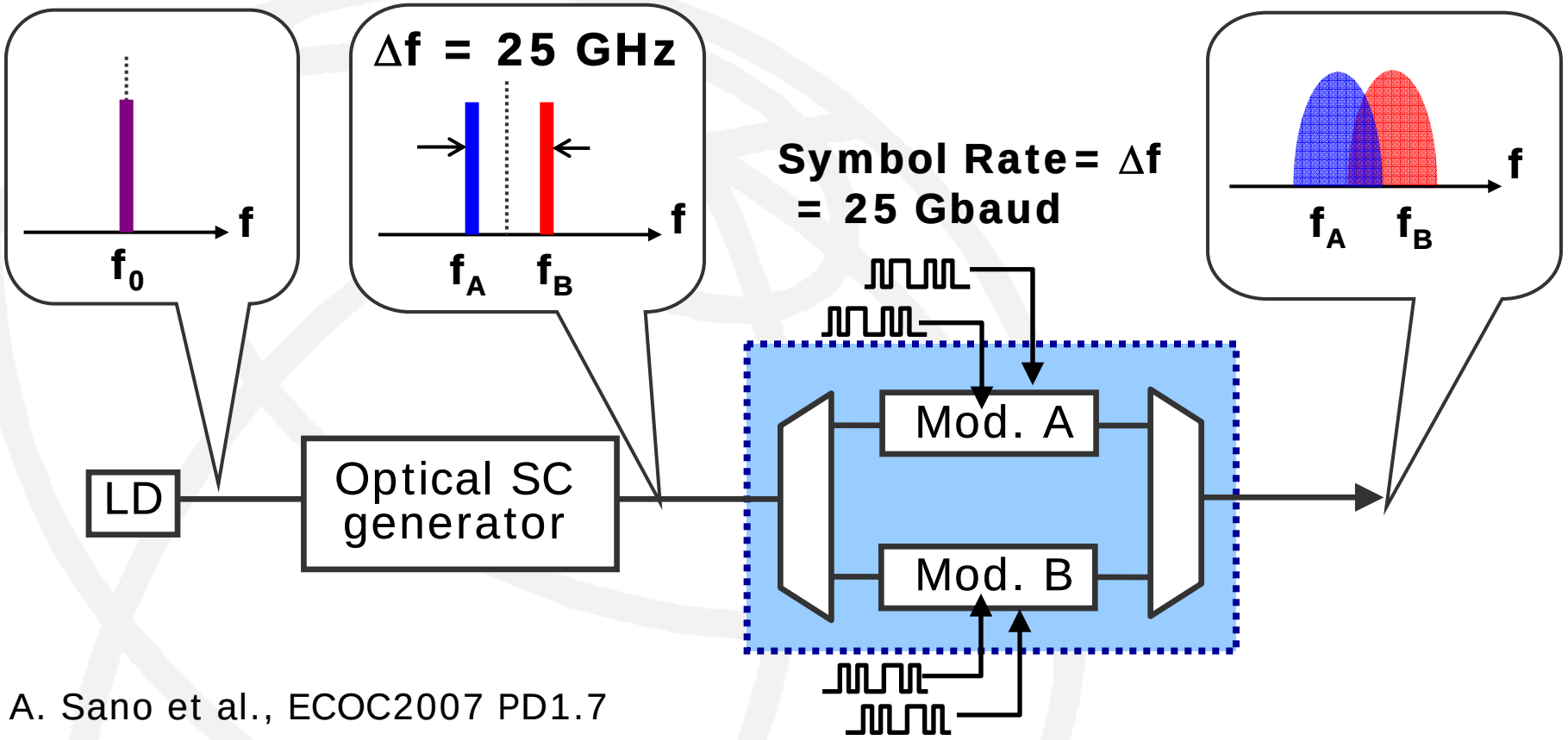
Tolerance to band filtering in ROADM nodes



Further decrease in symbol rate (by increasing bits/symbol)

2-subcarrier(SC)-OFDM-DQPSK Modulator

All-Optical OFDM Modulation

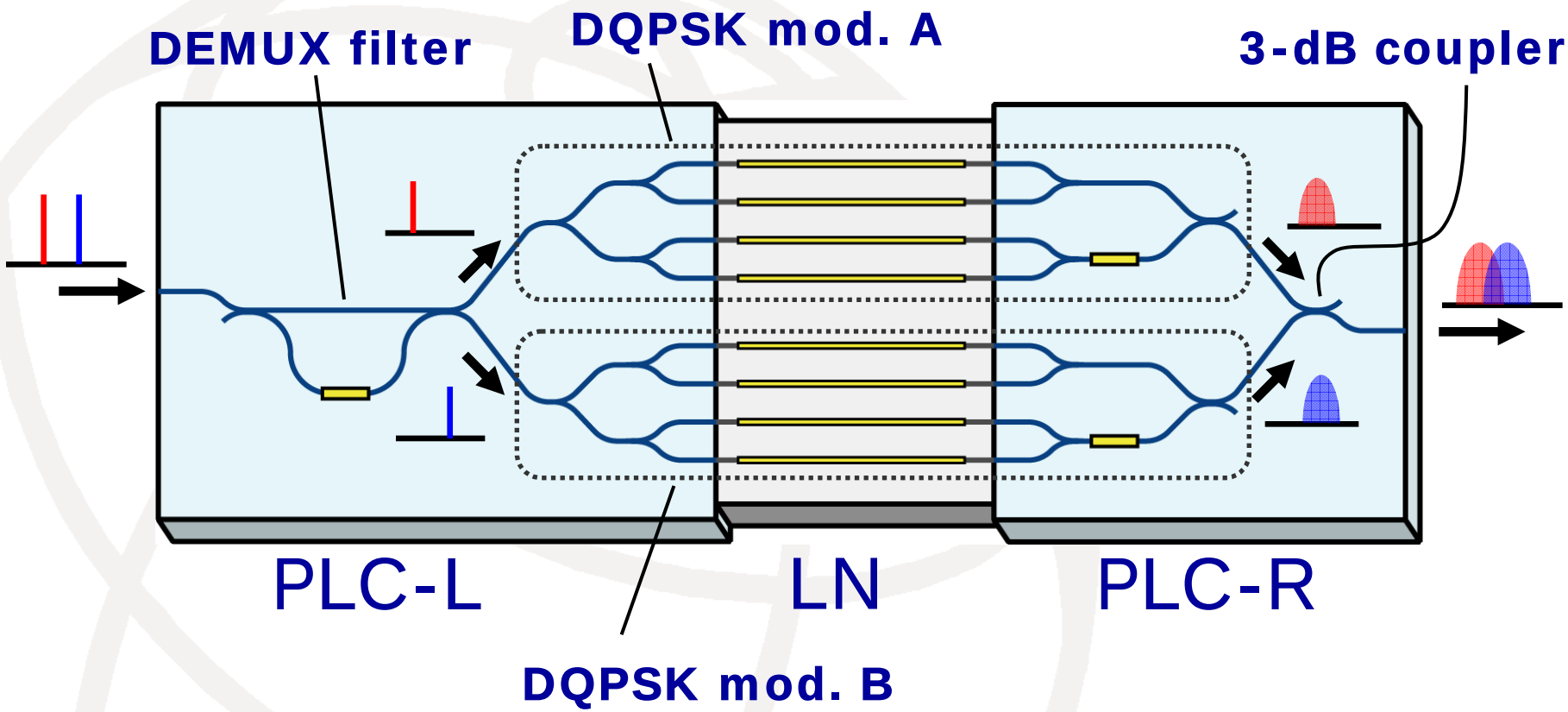


A. Sano et al., ECOC2007 PD1.7

Integrated Modulator

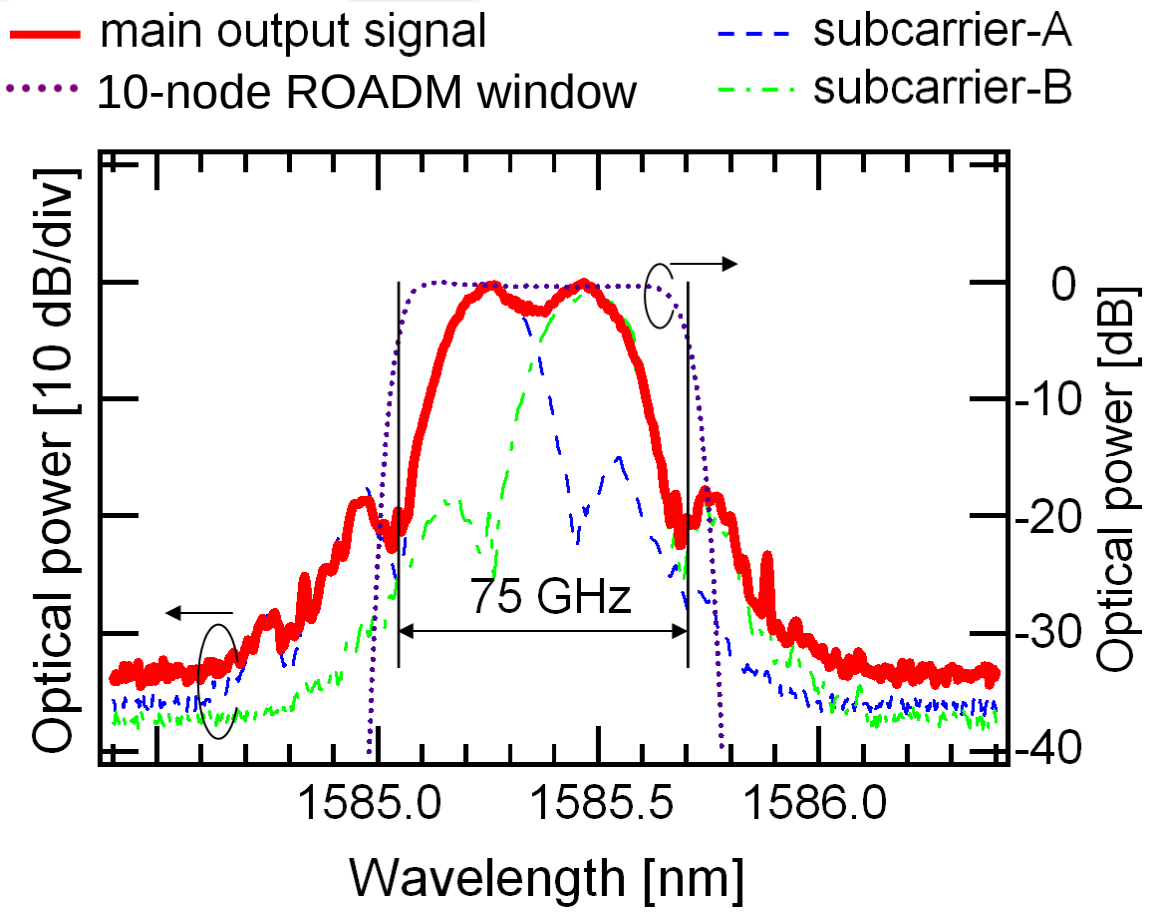
4 bit/symbol (100 Gb/s with 25 Gbaud)

Modulator Circuit



Total insertion loss: 6.5 dB

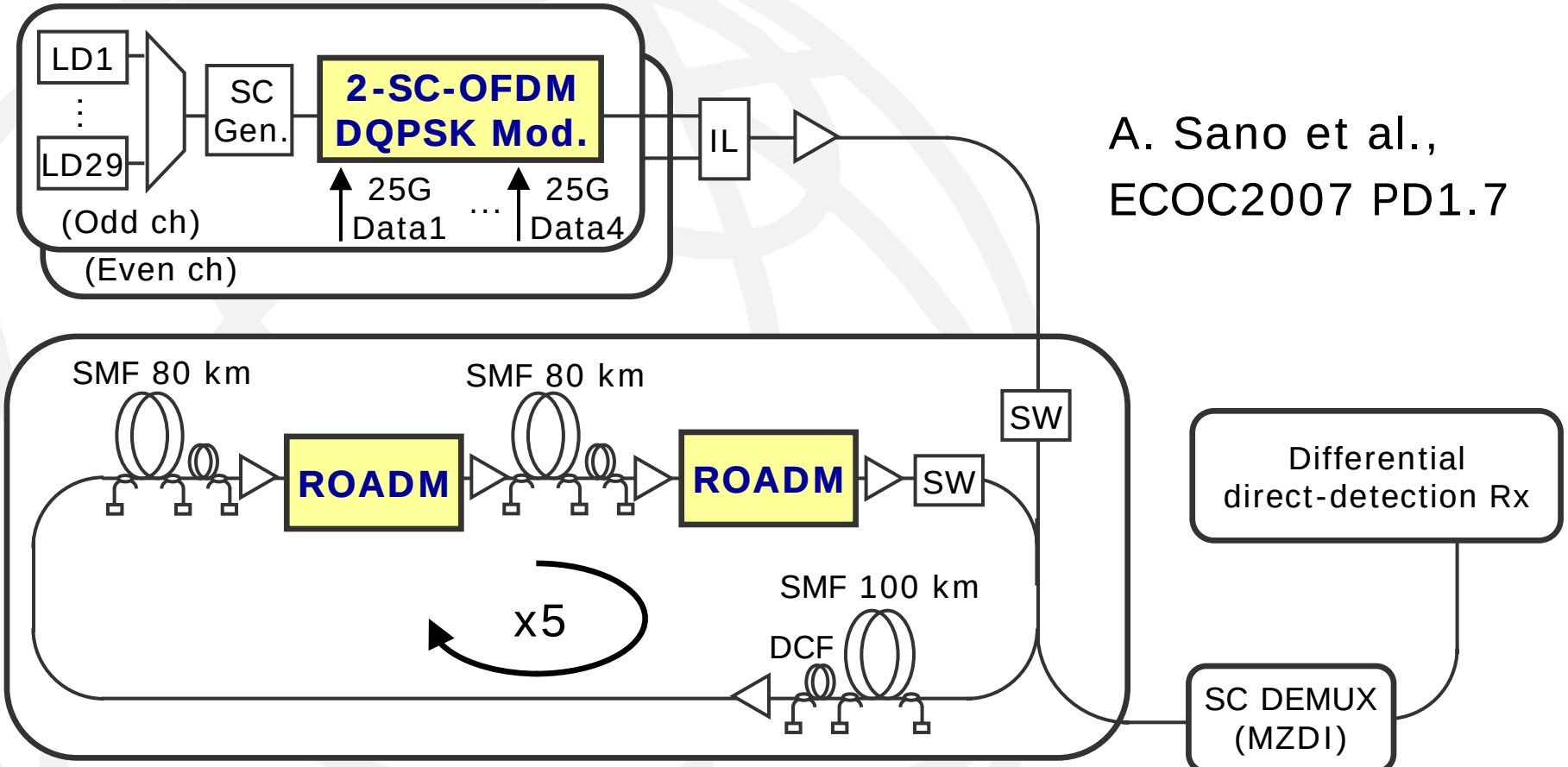
2-SC-OFDM-DQPSK Signal Spectra



100 Gb/s with 75-GHz bandwidth

Setup for Transmission Experiment

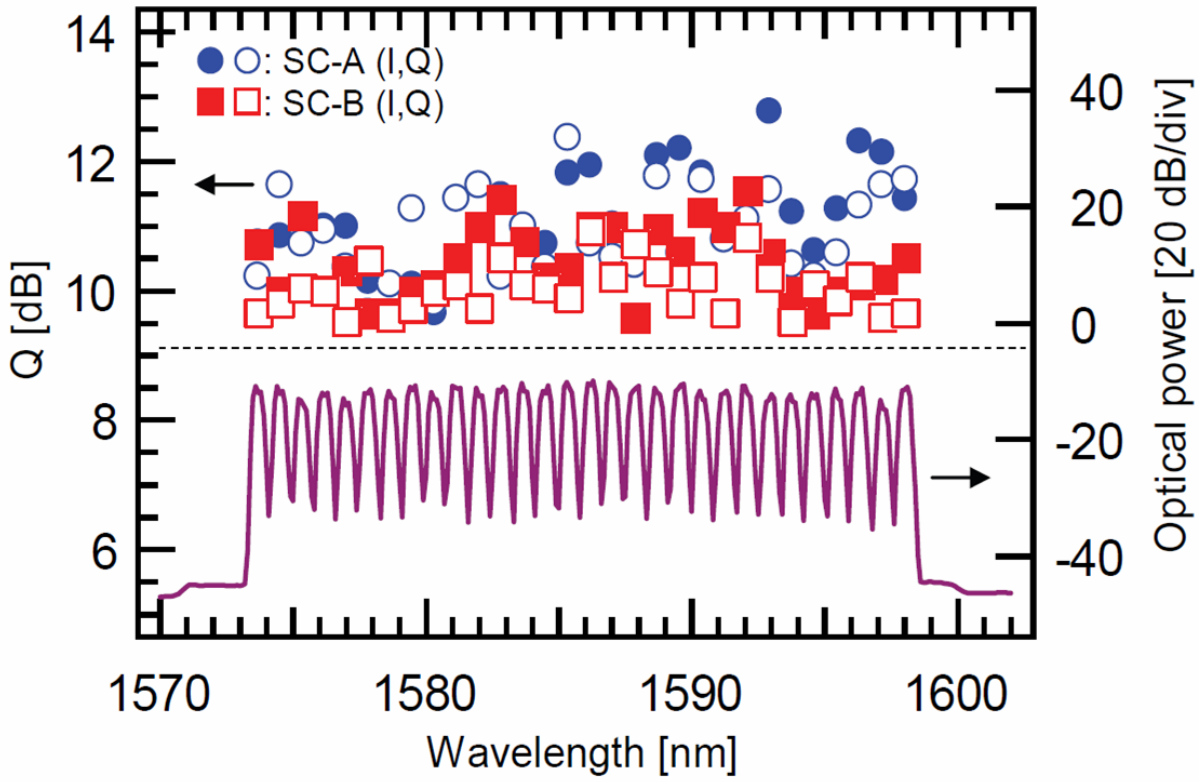
100 Gb/s x 30λ Tx



A. Sano et al.,
ECOC2007 PD1.7

1300-km transmission line w/ 10 ROADM nodes

Q-factor & Received Optical Spectra



Successful transmission over
1,300-km SMF with 10 ROADM nodes

Conclusion

PLC-LN hybrid modulators

- High-speed LN phase modulators

  + Low-loss Silica PLCs

- High integration scalability

Promising for future 100G/λ-class transport networks

Thank you.