Regeneration of Phase Encoded Signals: Different Schemes and Future Issues

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WS3

All-Optical Processing of Advanced Modulation Format Signals

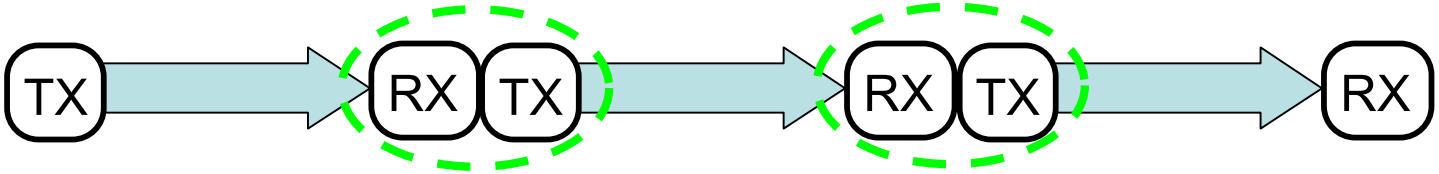
ECOC2010, September 19, 2010

Outline

- Different Regeneration Schemes for Phase-Encoded Signals
- Phase Regeneration Using Amplitude Regenerators
- Issues in Using All-Optical Regenerators in Real Systems

All-Optical Regeneration

Long-distance systems need signal regeneration.



Some or all of the electrical regenerators are desired to be replaced by all-optical regenerators.

All-optical regenerators
- higher-speed operation
- lower power consumption
- less format-dependent

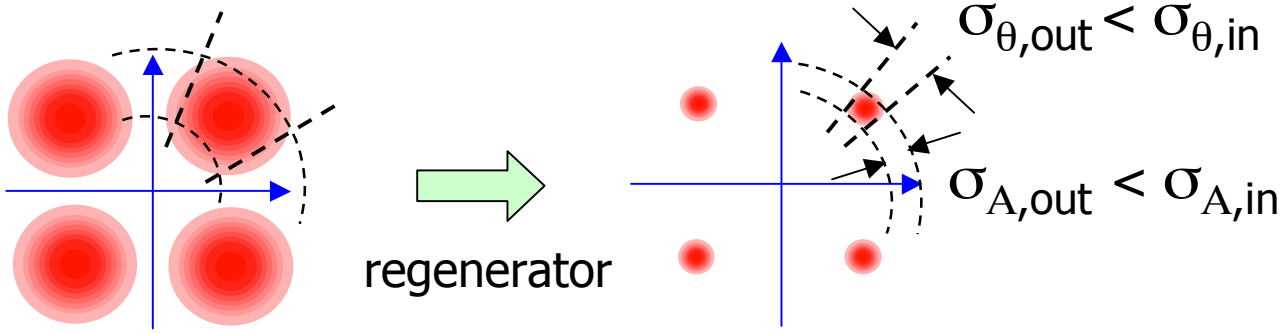
Issues

◆ *Regenerators for signals in advanced modulation formats ((D)BPSK, (D)QPSK, 8PSK, QAM,....) is yet to be explored.*

◆ *Regenerators work (only) when signal pulses to be regenerated are well isolated in time.*

- *DEMUX/MUX are needed for regeneration of WDM signals.*
- *Dispersion compensation is needed before the regenerator.*

Regeneration of PSK signals



Regeneration of PSK signals is challenging.

It is difficult to detect and manipulate optical phase.

Schemes of PSK signal regeneration

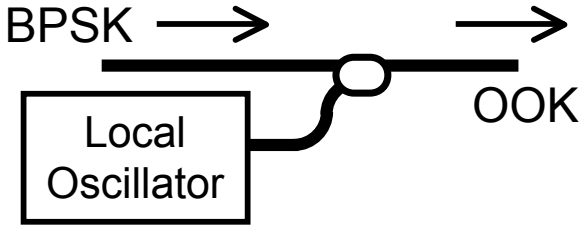
1. Phase-preserving amplitude regeneration
   - •Saturated fiber-optic parametric amplifier
   - •Asymmetric NOLM
   - •Semiconductor saturable absorber
2. Phase and amplitude regeneration using (D)PSK to OOK demodulation and amplitude regeneration
3. Phase and amplitude regeneration using phase-sensitive amplifier

Phase and Amplitude Regeneration Using Amplitude-Only Regenerator

Phase modulation

Demodulation using delay interferometer

Coherent demodulation



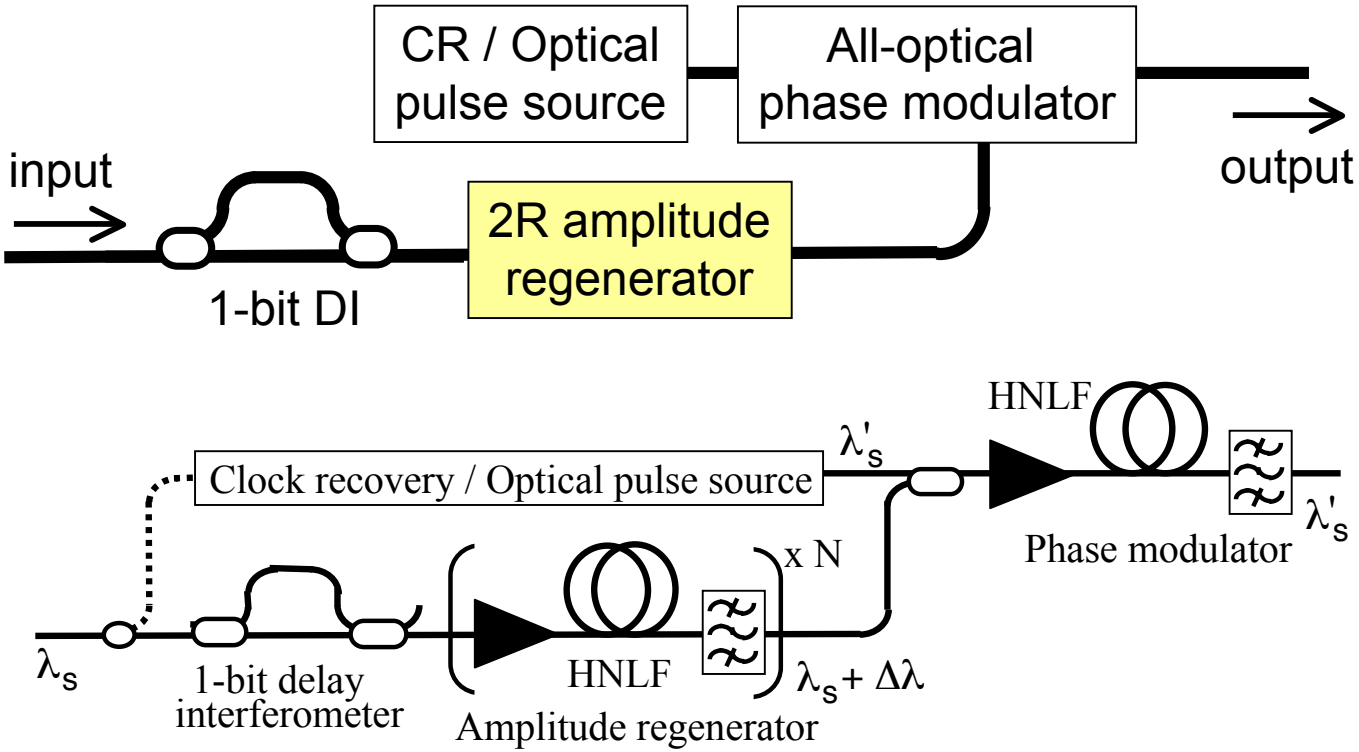
Amplitude modulation

Amplitude regenerator

(The amplitude regenerator does not need to preserve signal phase.)

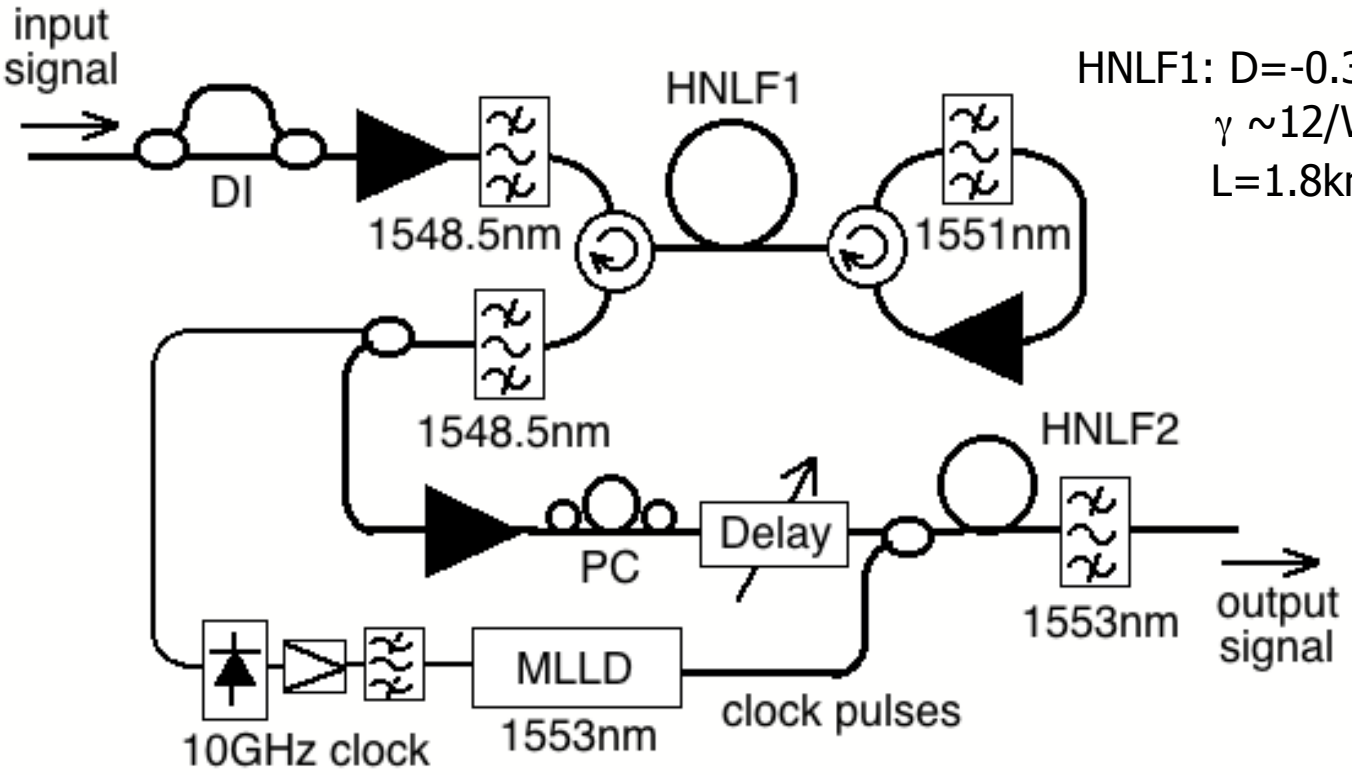
Amplitude information is transferred back to phase information.

DPSK Regenerator Using a Straight-Line Phase Modulator



M. Matsumoto, PTL17, 213 (2007).

Experimental Setup



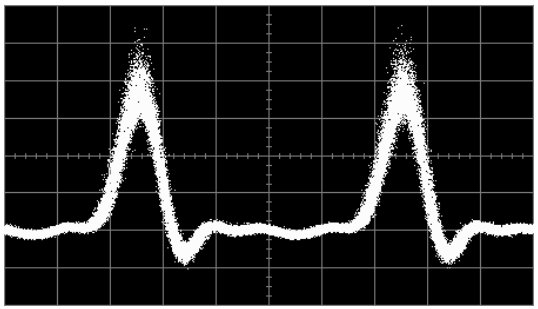
HNLF1: D=-0.35ps/nm/km
γ ~12/W/km
L=1.8km

- Two-stage Mamyshev regenerator in bidirectional configuration is used.
- Mode-locked semiconductor laser diode (MLLD) is used as a clock source.
- XPM-based all-optical phase modulation is used.

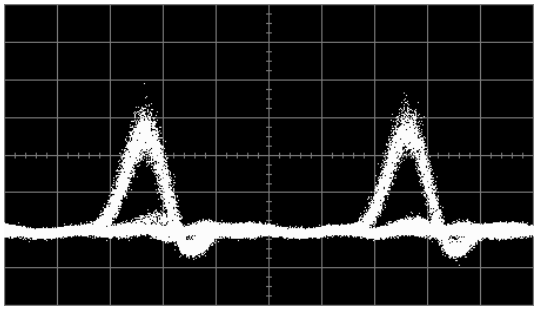
M. Matsumoto and H. Sakaguchi, OE16, 11169 (2008)
M. Matsumoto and Y. Morioka, OE17, 6913 (2009)

Experimental Result

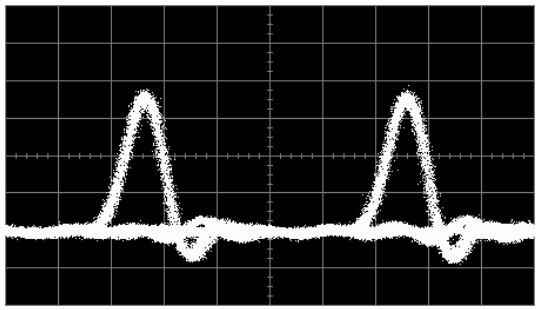
Waveforms in the regenerator (10Gbit/s)



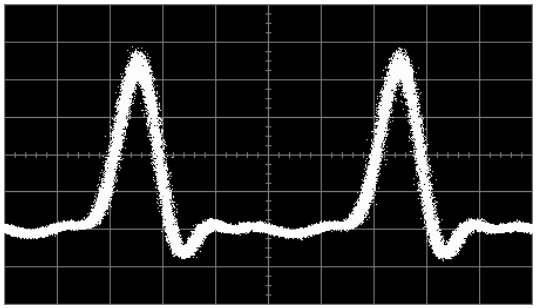
input signal (A)



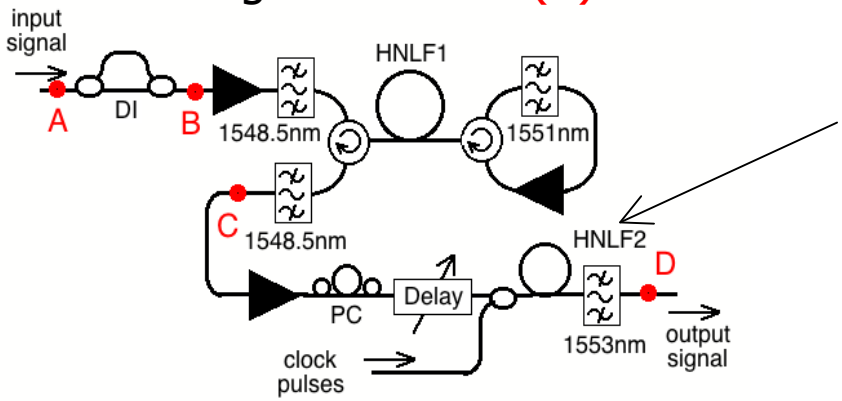
OOK signal after DI (B)



OOK signal after 2R (C)



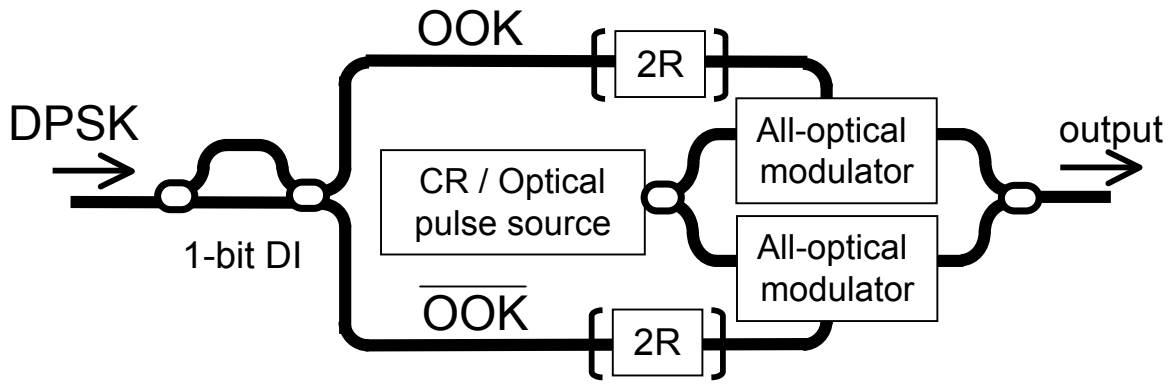
output signal (D)



HNLF: D=2.2ps/nm/km
γ ~12/W/km
L=2.4km

$\Delta\lambda$=4.5nm, walkoff time =24ps

DPSK Regenerator Using a Mach-Zehnder Interferometer Modulator



- Complementary OOK signals drive all-optical modulators in MZI.

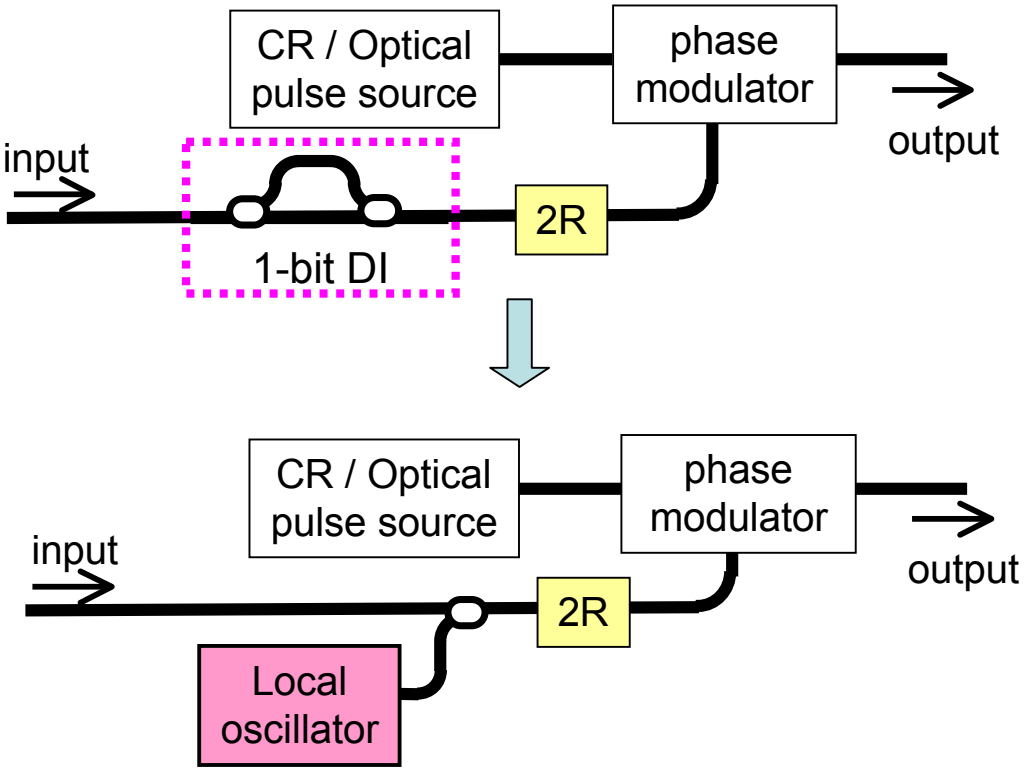
I. Kang et al.,Th4.3.3,ECOC2005 (2005)
P. Vorreau et al.,PTL18, 1970 (2006)
Ch. Kouloumentas et al.,PTL22, 1187 (2010)

- All-optical modulators in MZI can be either phase or amplitude modulators.

- When the all-optical modulators are saturable, 2R can be removed.

BPSK Regenerator Using Coherent Demodulation

Demodulation from DPSK to OOK by DI may be replaced by coherent demodulation.



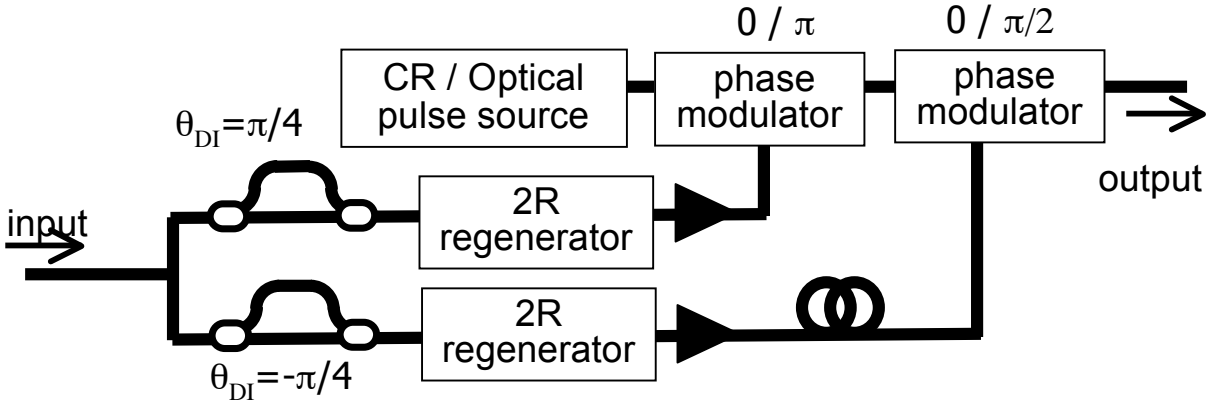
✓Required strength of 2R can be halved.

✓Logic of the signal is preserved.

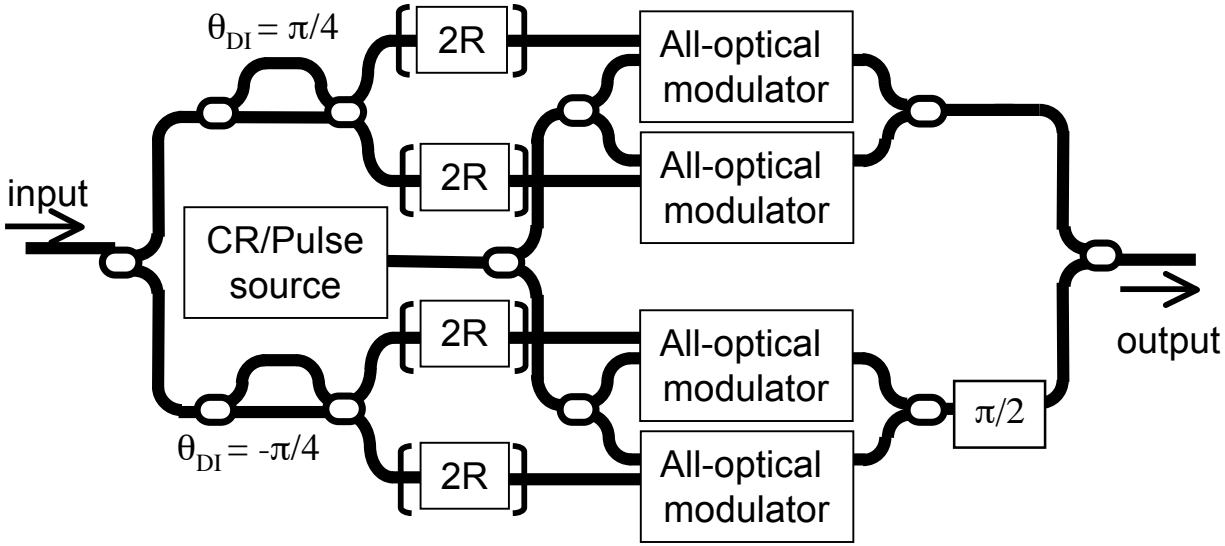
◆ Phase-locked local oscillator is needed.

(D)QPSK Regenerator Using Amplitude Regenerators

1. Regenerator using straight-line phase modulators



2. Regenerator using MZI

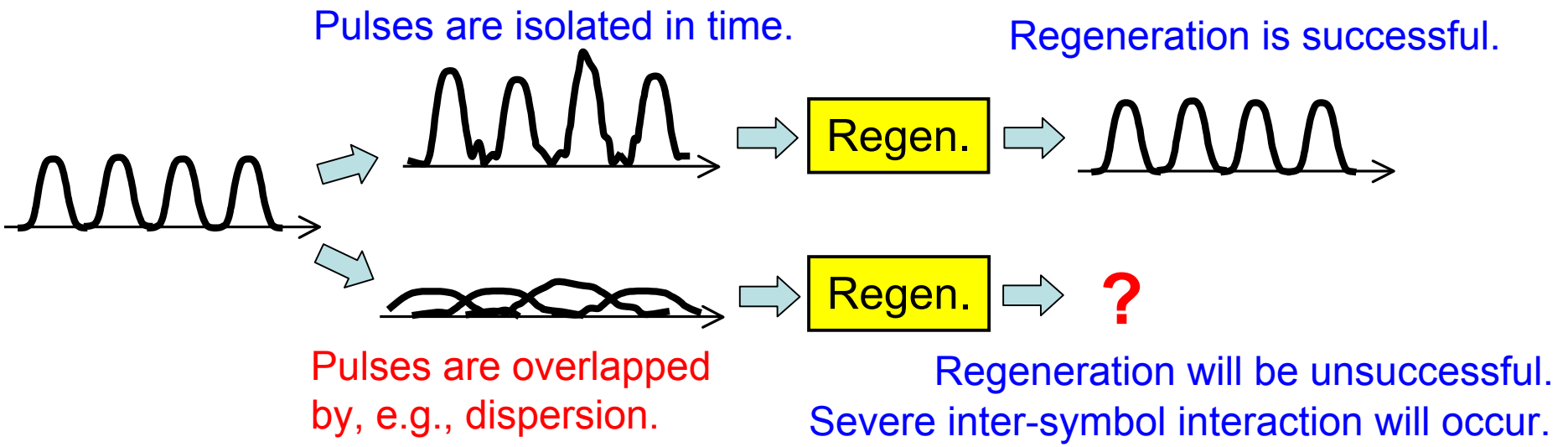


Demodulation from DQPSK to OOK by DI can be replaced by coherent demodulation (X. Yi et al., JLT28,587 (2010).

Issues

All-optical regeneration works when signal pulses are isolated in time when they are launched into the regenerator.

1. WDM signals should be demultiplexed before the regenerator.
2. Dispersion should be optically compensated before the regenerator.



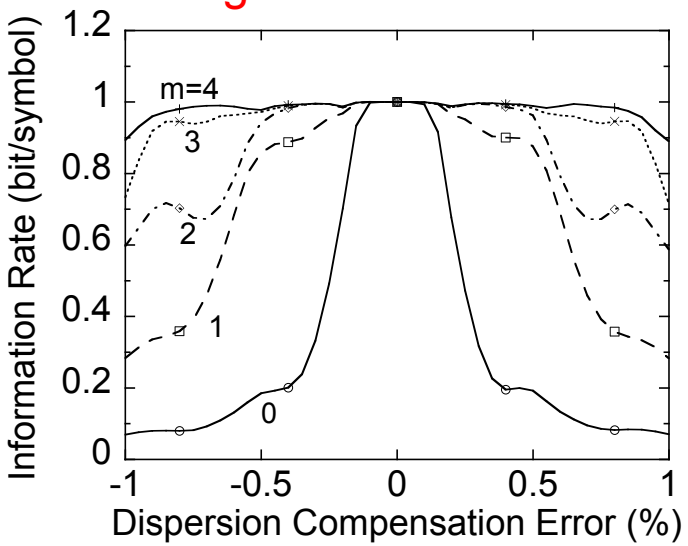
Issues

Inter-symbol interaction may be mitigated by signal processing at the receiver such as *Maximum Likelihood Sequence Estimation*.

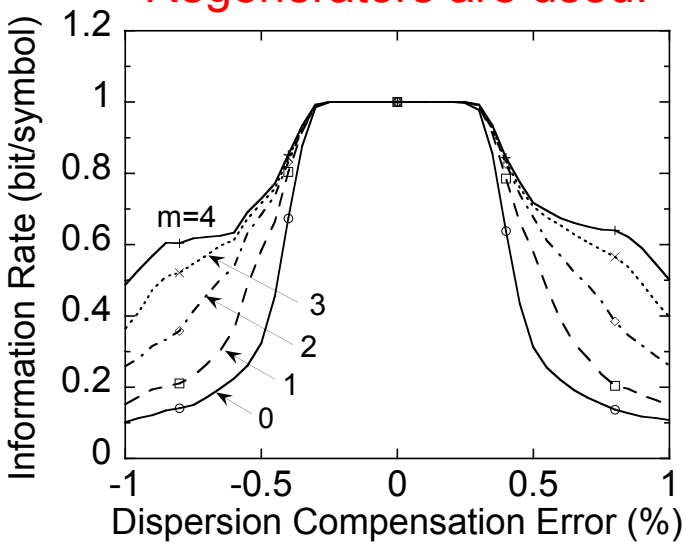
Performance evaluation of the system including all-optical regenerators in terms of *information rate*, or *channel capacity*, considering channel memory is useful.

Example:
Information rates of an OOK system with imperfect dispersion compensation

No regenerators are used.



Regenerators are used.



m: length of channel memory

Summary

All-optical regeneration of phase-encoded signals was discussed.

- ❑ Phase and amplitude regeneration scheme using (D)PSK to OOK demodulation and amplitude regeneration
  - Two schemes using straight-line phase modulators and MZI modulators were described.
  - Demodulation from (D)PSK to OOK by delay interferometer can be replaced coherent demodulation.
  - (D)QPSK regeneration is feasible.
- ❑ Issues in using all-optical regenerators in practical systems
  - How to deal with the inter-symbol interaction caused by the regenerators was discussed.