Athermal Demodulator for 42.7-Gb/s NRZ-DPSK Signal

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Introduction

Optoplex CORPORATION

- Differential phase-shift keying (DPSK) has become an attractive modulation format for high speed optical transmissions.
  - high receiver sensitivity and high nonlinear tolerance.

- For direct detection of DPSK signal, a demodulator is needed. Conventionally, the demodulator is an optical 1-bit delay interferometer (1-bit DI).

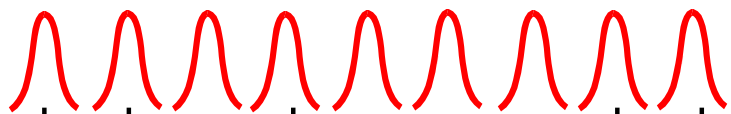
- 1-bit DIs are conventionally based on an all-fiber design or a planar lightwave circuit design.
  - These designs are intrinsically temperature sensitive, so accurate temperature control and stabilization of the DI are required.

- Here, we report the demonstration of an athermal DI, based on a free-space optical design.
  - All-passive, compact, no monitoring and feed-back control needed.
  - Suitable for any ITU channels.

=> **Lower CapEx and OpEx.**

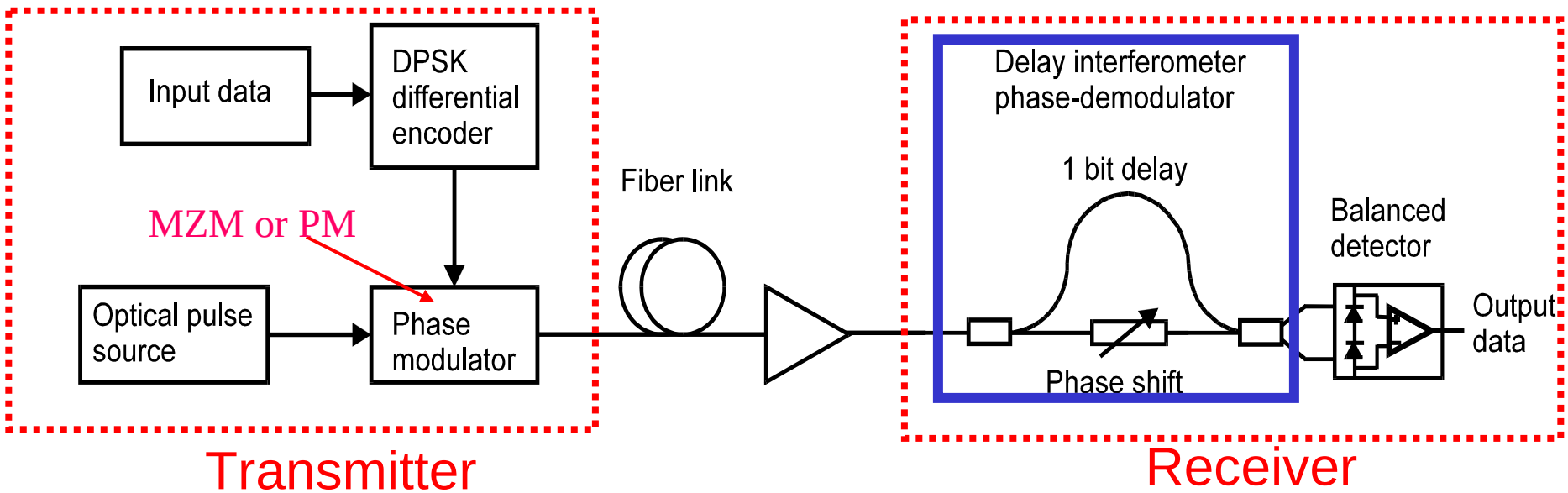
DPSK Implementation

Transmitted data: 0 1 1 1 0 0 1 0 ...



Differentially encoded phase: + + – + – – – + + ...

equal intensity in every time slot

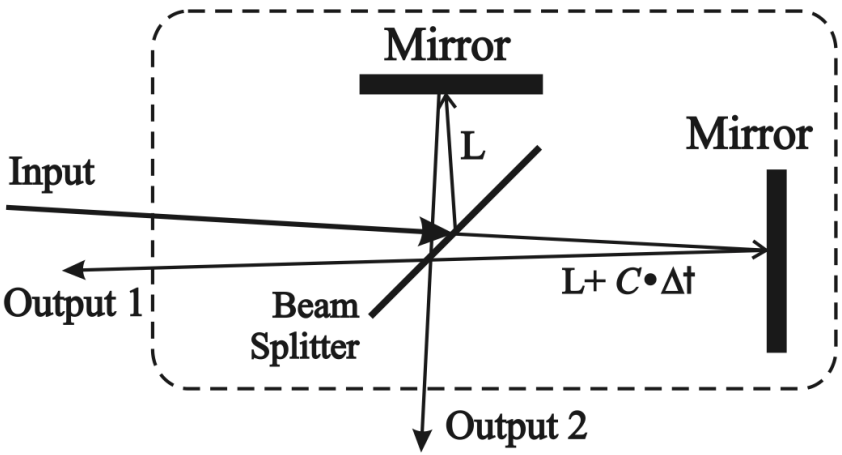


Athermal Delay-Interferometer* (A-DI)

(*: Optoplex and Lucent patents pending)

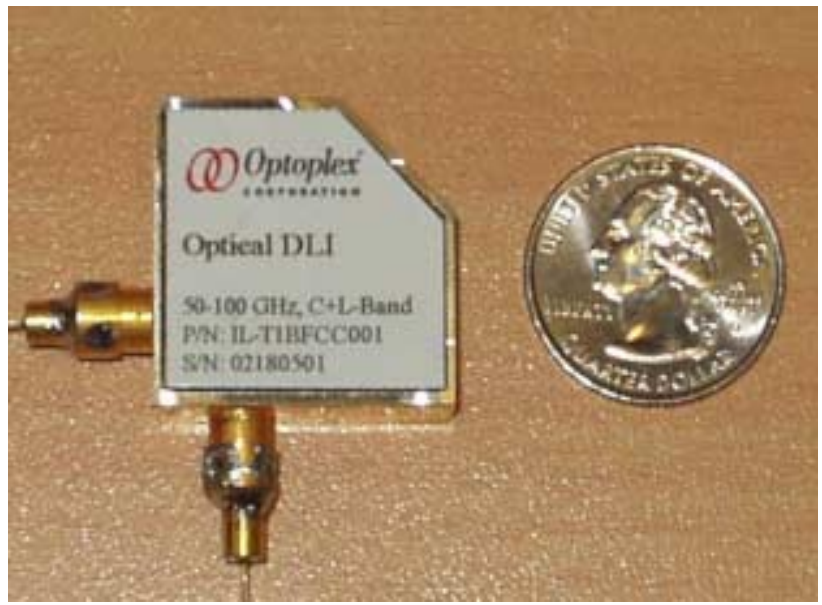
Schematic of the A-DI

- Based on a free-space optical Michelson interferometer.



C is the speed of the light, L is the round-trip length of one path, and Δt=20ps is the round-trip time delay between the two paths of the DI.

A picture of the A-DI.



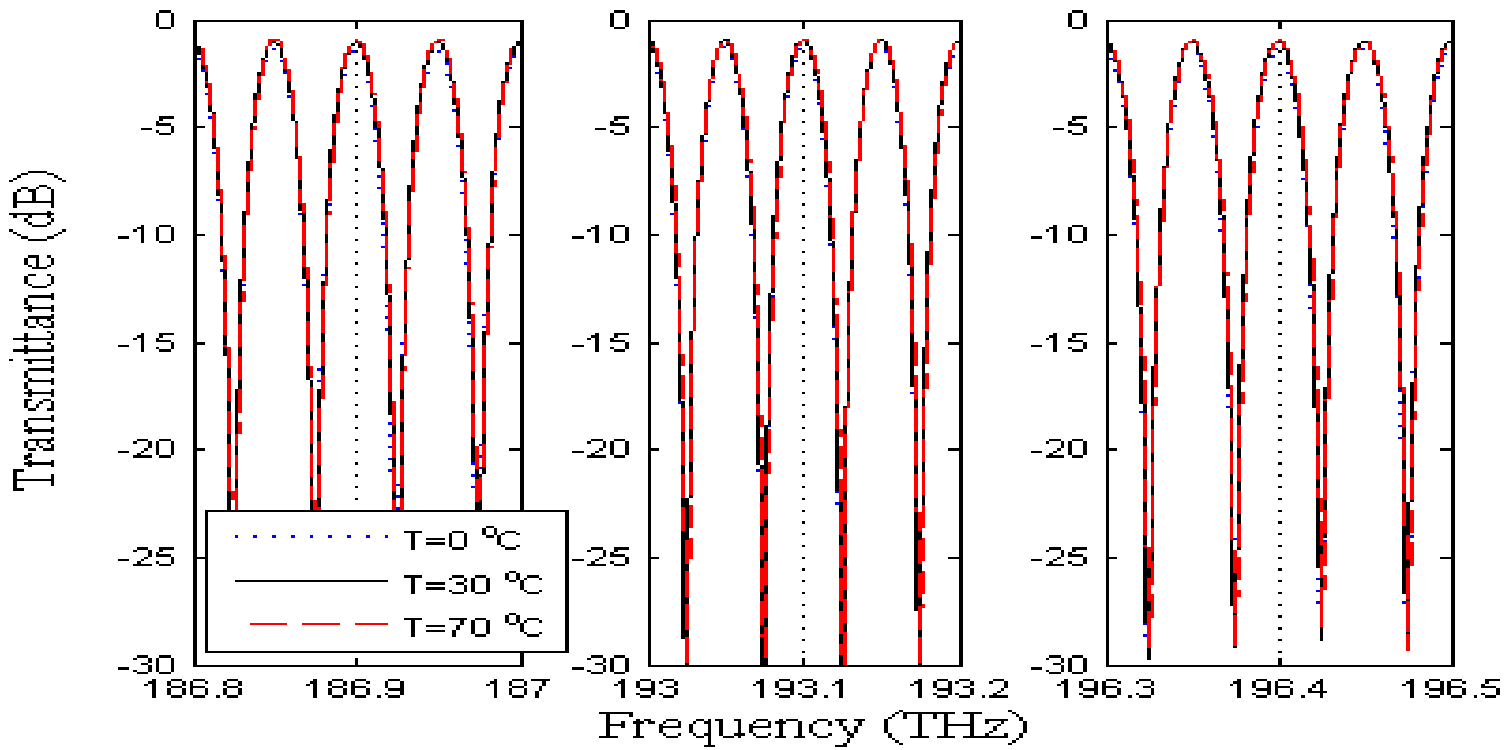
Based on the same free-space optical design, thermally tunable DI (with short response time) is also available from Optoplex.

Unique characteristics of the A-DI

1. FSR=50 GHz, and Locked onto the ITU (*patent pending*).
   - Capable of decoding any ITU channel
2. Frequency offset over the C+L band: <±0.5 GHz.
3. Temperature-induced frequency offset: <±0.5 GHz over [0, 70°C].
4. Polarization dependent frequency offset: <±0.15 GHz.
5. Size: 27mmx27mmx10mm.
6. Loss: <1.5 dB.
7. Hermetically sealed.
8. All passive: no power needed.
9. Athermal: no temperature control needed.

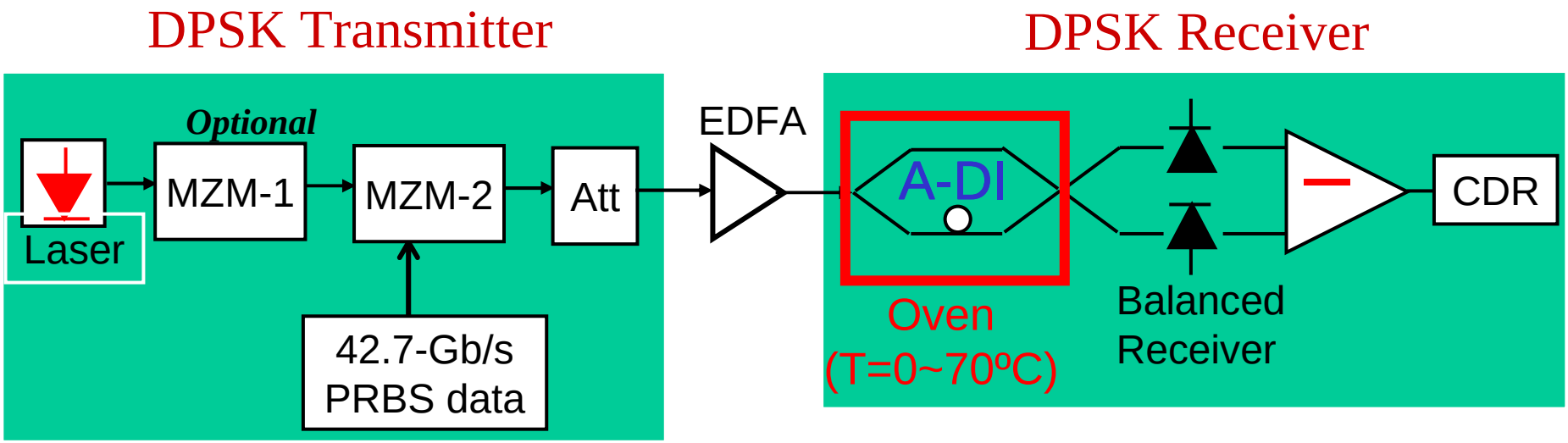
Passband Characteristics of the A-DI

The measured transmission curves at the constructive port of the A-DI at 0°, 30°, and 70°C.



Unnoticeable frequency offset over C+L band in [0°,70°C] !

Experimental Setup
- 42.7-Gb/s NRZ-DPSK and 67%RZ-DPSK



MZM1: RZ pulse carver;
MZM2: DPSK data modulator
(PRBS length: 2^{31}-1)
Att: optical attenuator;
EDFA: optical pre-amplifier;

A-DI: Athermal DI;

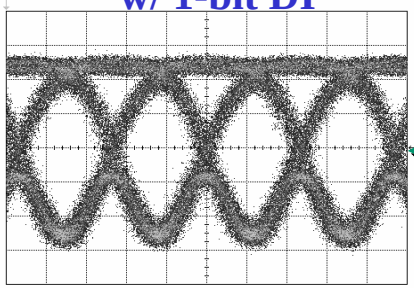
−: differential amplifier.

CDR: Clock-data recovery.

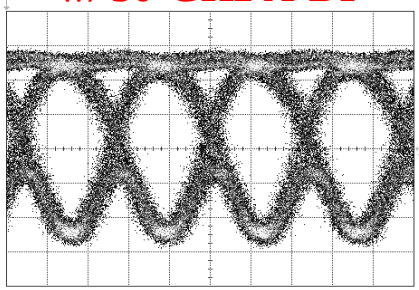
Eye Diagrams and BER performance

Measured eye diagrams of 42.7-Gb/s DPSK signals.

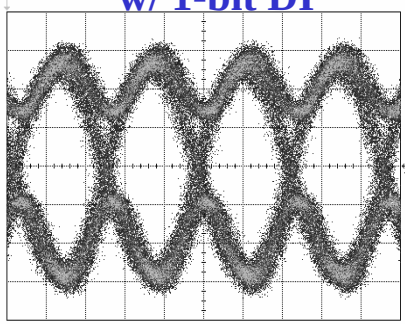
NRZ-DPSK w/ 1-bit DI



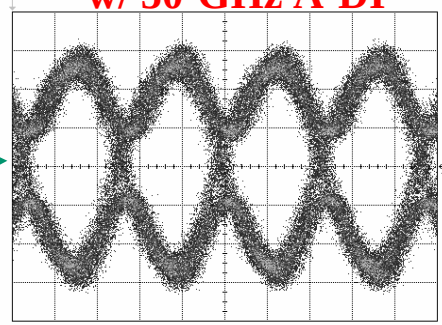
NRZ-DPSK w/ 50-GHz A-DI



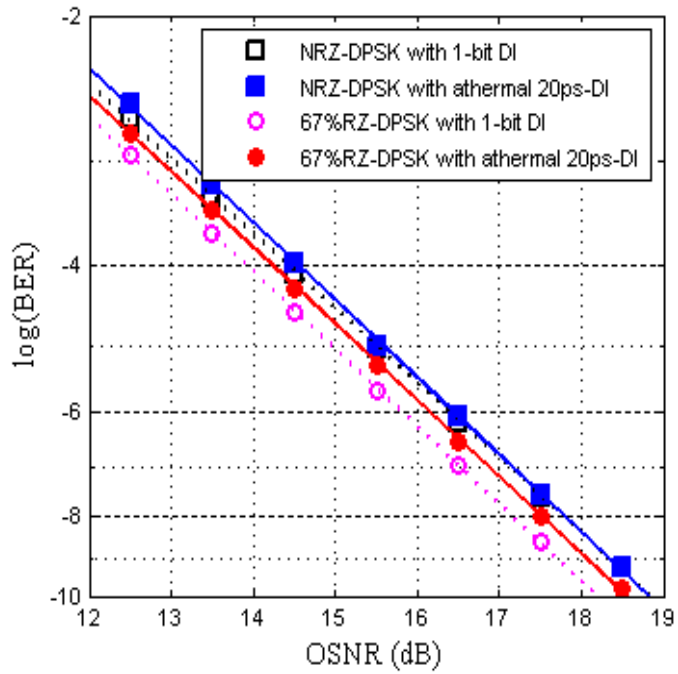
67%RZ-DPSK w/ 1-bit DI



67%RZ-DPSK w/ 50-GHz A-DI

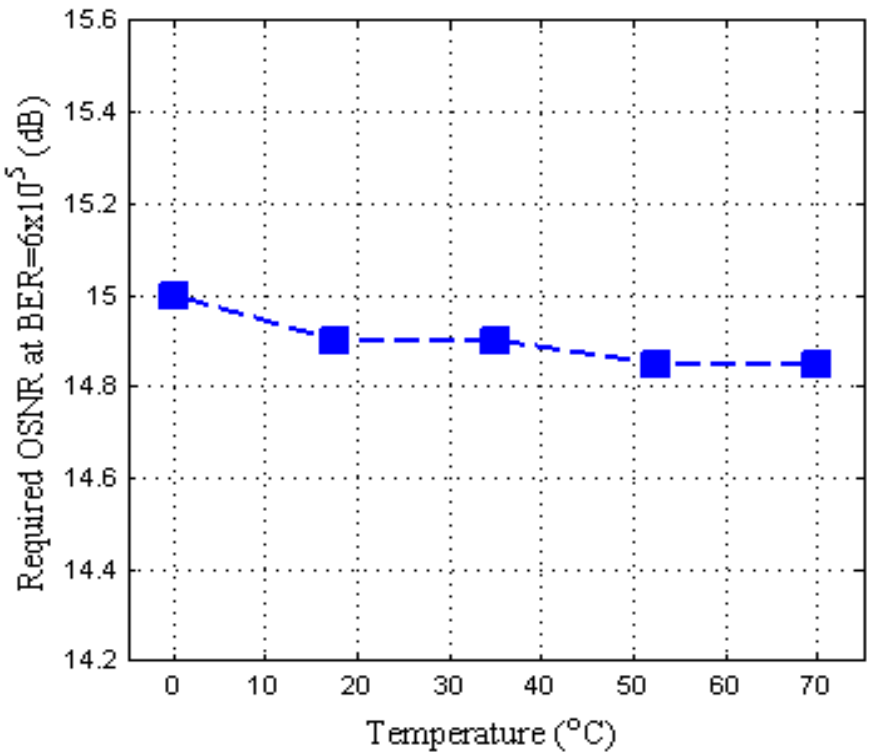


Measured BER performance of the 42.7-Gb/s NRZ-DPSK and 67%RZ-DPSK signals.



Temperature Dependence

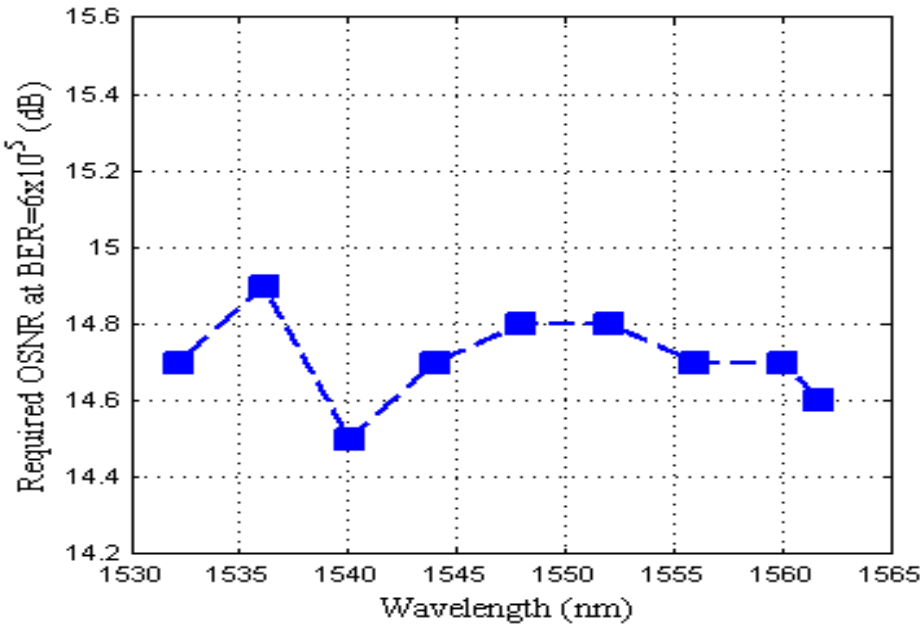
Measured OSNR requirement vs. Temperature for a 42.7-Gb/s NRZ-DPSK signal with the A-DI.



In the temperature range from 0 to 70 °C, the temperature-induced penalty is <0.15 dB.

Wavelength Dependence

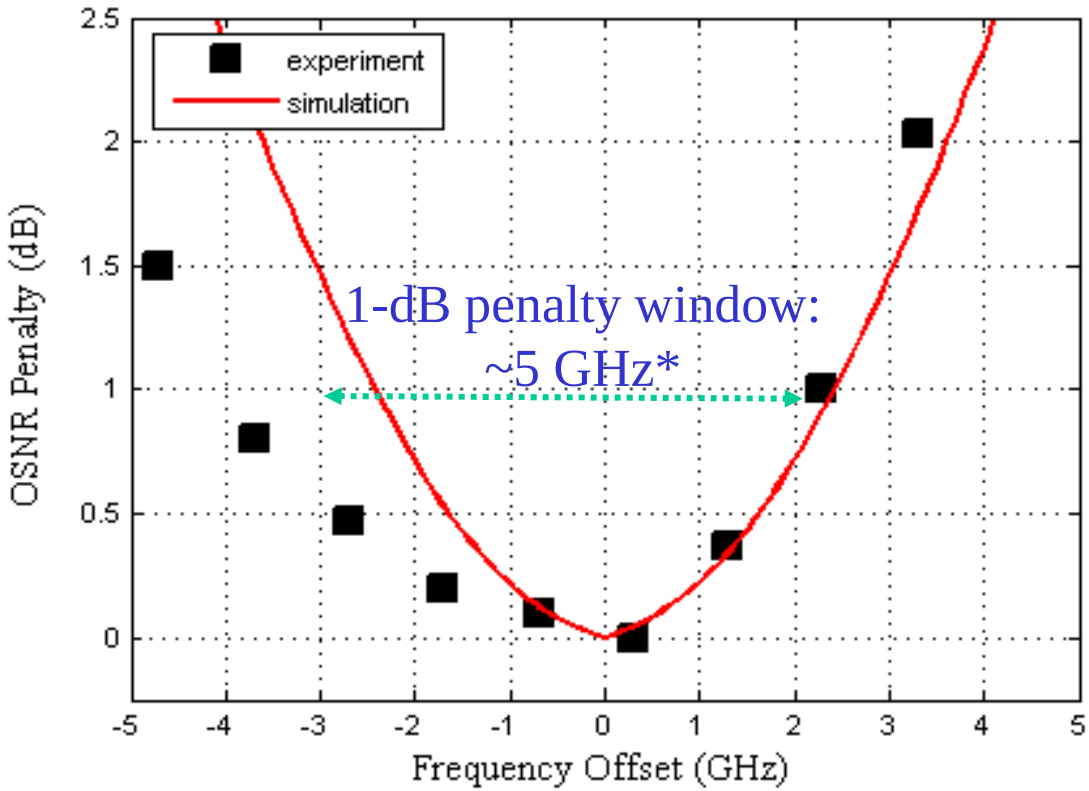
Measured OSNR requirement of 42.7-Gb/s NRZ-DPSK signals over the C-band. The channels are set on the ITU grid using a wavemeter.



Remarkably, the OSNR requirement only varies ~±0.2 dB across the entire C-band.

Given the similarly small frequency drift in the L-band, we expect the athermal DI to have similar performance in the L-band.

Impact of Laser Frequency Offset



***: Feasible with commercially available frequency-locked lasers.**

Discussion

The athermal DI also provides a few unique features.

1. No need for monitoring and feedback control (which unavoidably cause some tracking penalty).
   - Dithering of the phase of the DI is needed for feedback control

2. Unambiguous determination of the data and the inverted data.
   - The eye diagrams for the constructive and destructive ports of the DI are indistinguishable for RZ-DPSK.

3. Capability of simultaneously demodulating multiple ITU channels, and compatibility with fast wavelength tuning signals.

Summary

• We have demonstrated an athermal optical delay interferometer capable of demodulating OC-768 NRZ-DPSK and RZ-DPSK signals that are on the ITU grid, with negligible penalty over a temperature range of 0~70°C.

•With its simplicity, compactness, and no need for temperature control and stabilization, this DPSK demodulator may be attractive for reliable and cost-effective product implementations.

Thanks for your attention!