



64-GBd DP-Bipolar-8ASK Transmission over 120 km SSMF Employing a Monolithically Integrated Driver and MZM in 0.25- μm SiGe BiCMOS Technology

Gilda Raoof Mehrpoor^{1,4}, Carsten Schmidt-Langhorst², Benjamin Wohlfeil¹, Robert Elschner², Danish Rafique¹, Robert Emmerich², Annika Dochhan¹, Iria Lopez³, Pedro Rito³, Despoina Petousi³, Dietmar Kissinger³, Lars Zimmermann³, Colja Schubert², Bernhard Schmauss⁴, Michael Eiselt¹, Jörg-Peter Elbers¹

1: ADVA Optical Networking SE, Germany

2: Fraunhofer Heinrich Hertz Institute, Germany

3: IHP GmbH, Germany

4: LHFT, Friedrich-Alexander Universität Erlangen-Nürnberg, Germany



Motivation

Target Scenario:

Up **120 km** point-to-point connection, e.g. **data center interconnect**

IM-DD

- Low complexity
- Low component costs
- Small footprint
- Low power consumption
- Scalability difficult
- Low spectral efficiency

Coherent

- High complexity
- High component costs
- Large footprint
- High power consumption
- Good scalability
- High spectral efficiency

Silicon Photonics reduce cost, footprint, power consumption of transceiver optics



Makes coherent attractive for shorter distances!

Motivation

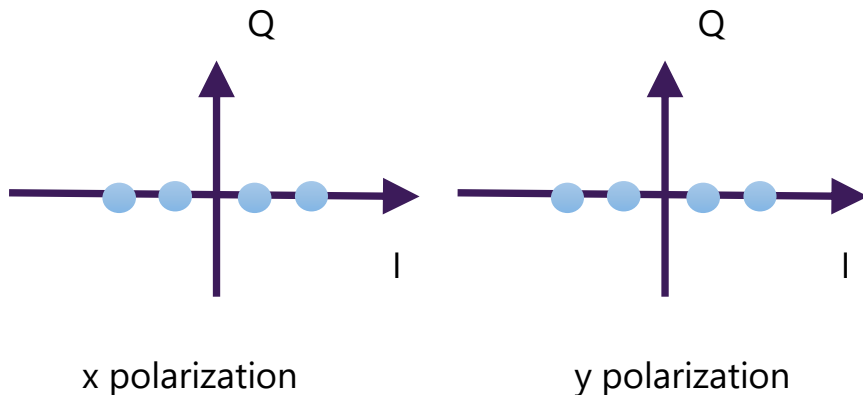
Goal: 64 GBaud dual polarization 64QAM = 600 Gbit/s

Requires: DP IQ MZ modulator

Available: single MZM

→ **Intermediate step:** 64 GBaud dual polarization mASK

DP-Bipolar-4ASK



IQ modulator can be fabricated with same structure as single MZM

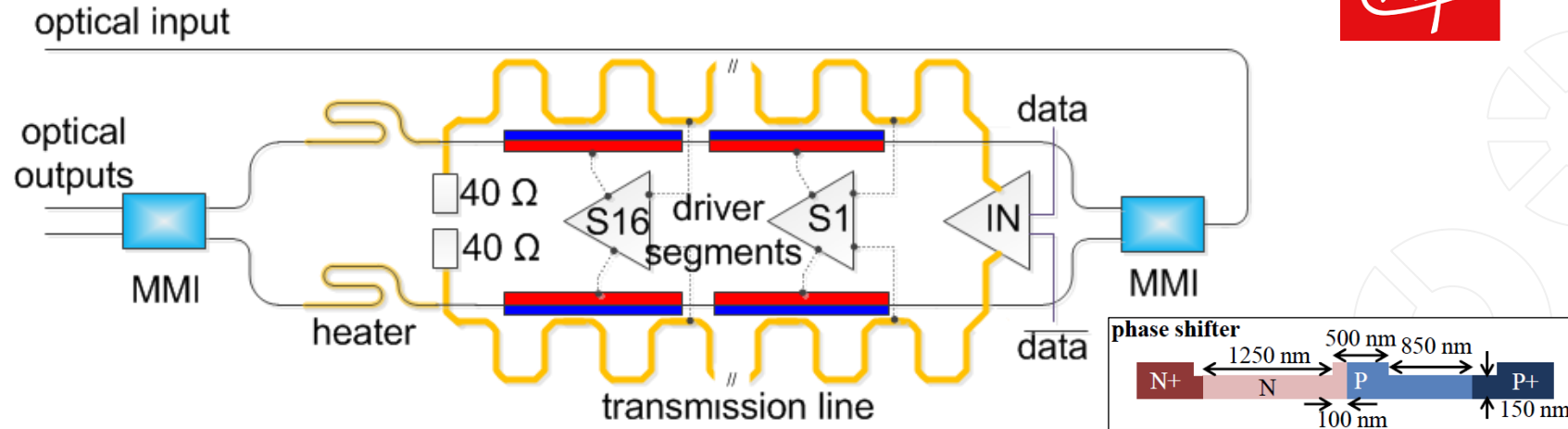
Outline

- 1 SiPh modulator with integrated driver
- 2 Experimental setup
- 3 Results – DP-*m*ASK transmission performance
- 4 Conclusion

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Silicon photonic modulator

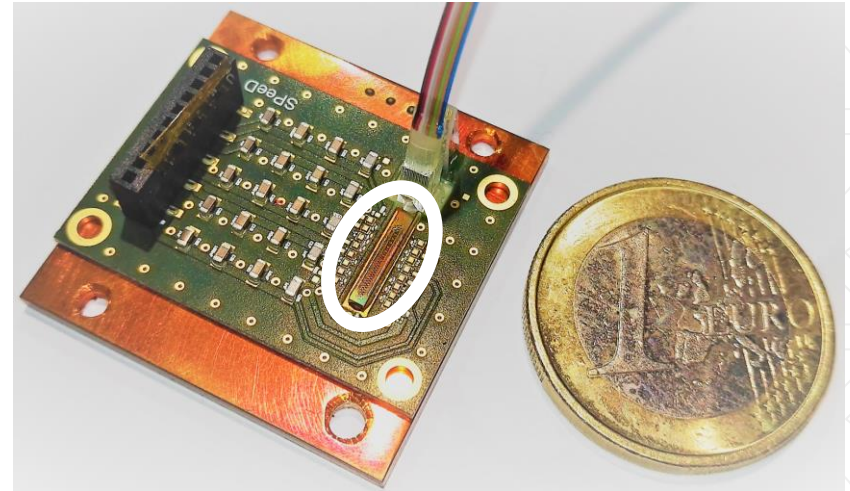


- Waveguide diode (carrier depletion) based phase shifters (6 mm length)
- Segmented driver with 16 segments + input stage
- Thermal heaters as static phase shifting elements for setting MZM bias point
- Multimode interference (MMI) couplers as optical power splitters
- Grating couplers and inverted tapers as fiber interface

Silicon photonic modulator



- Monolithically Integrated Driver and MZM in 0.25- μm SiGe BiCMOS Technology
 - Electronics on locally reconstructed bulk silicon
 - 11 mm x 1 mm footprint
 - 6 mm phase shifter length
 - ~ 1.8 W power consumption
 - ~ 18 dB insertion loss (fiber to fiber, 8 dB due to grating couplers)



Assembled by Fraunhofer IZM, Berlin

Silicon photonic modulator

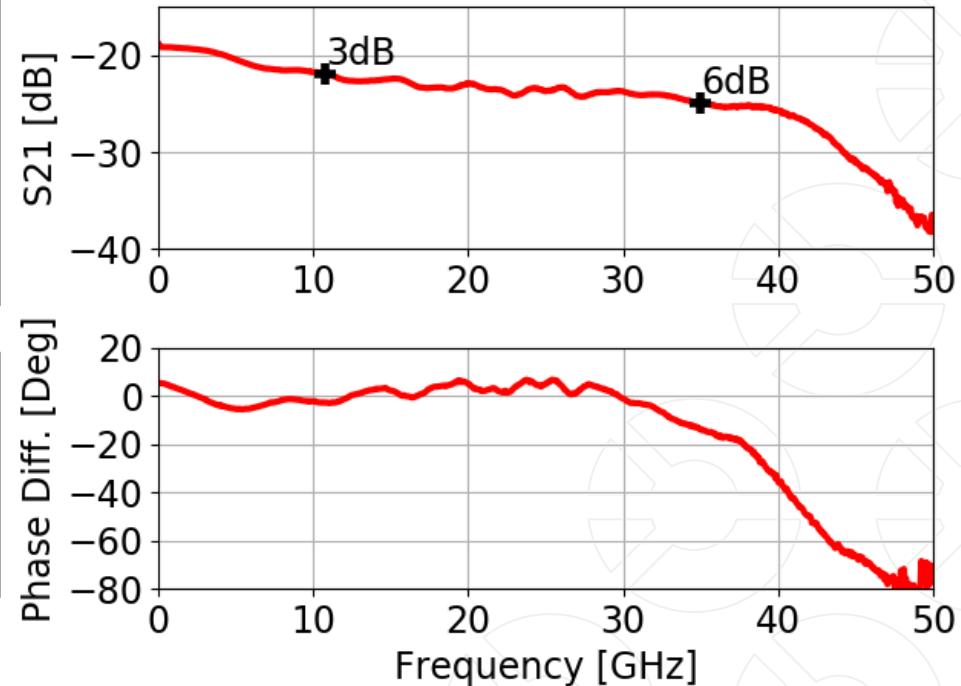


Combined (modulator + driver) S21 curve

- 3 dB bandwidth of 11 GHz
- 35 GHz 6 dB bandwidth
- Very flat curve up to 40 GHz

Deviation from linear phase

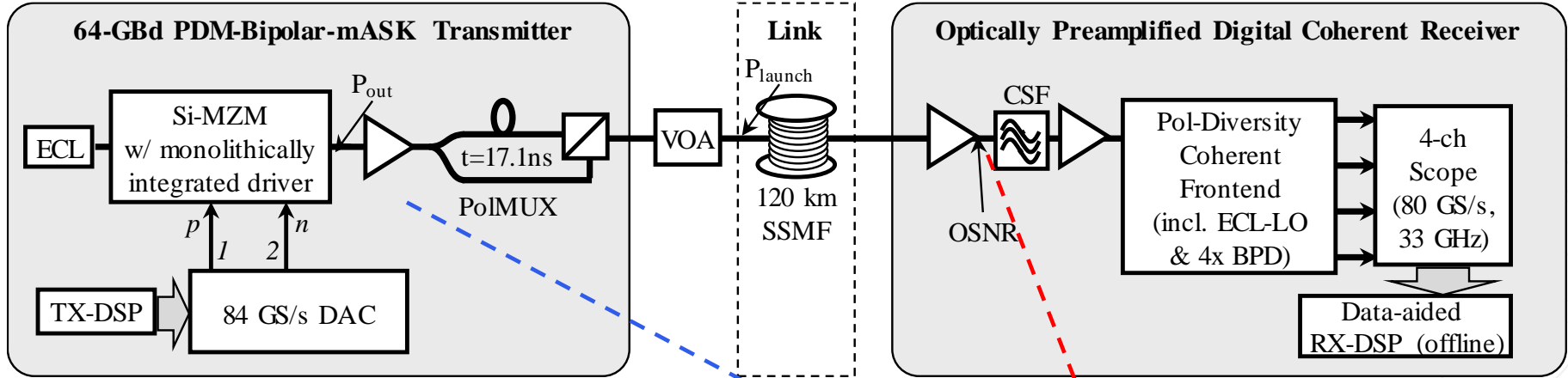
- Flat until 30 GHz
- Significant deviations beyond 30 GHz



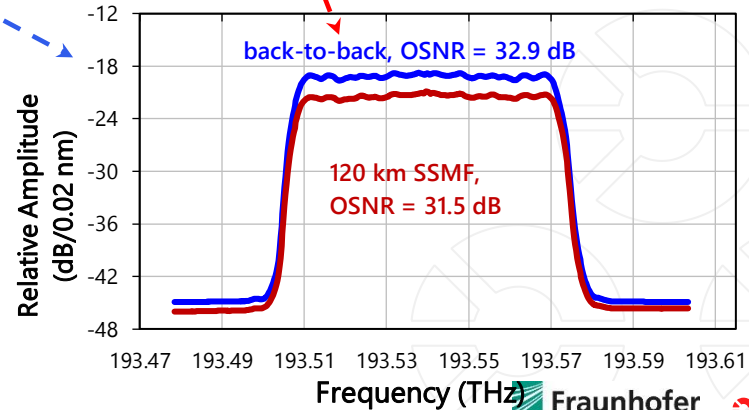
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Experimental setup



64 GBaud	
DP-Bi-2ASK	128 Gbit/s
DP-Bi-4ASK	256 Gbit/s
DP-Bi-8ASK	384 Gbit/s

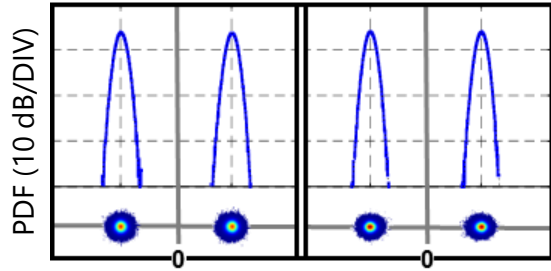


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Constellations and PDF

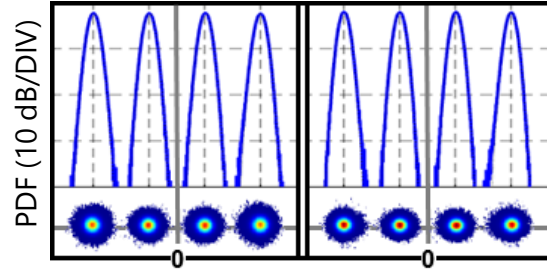
DP-Bi-2ASK



In-phase
X-Pol.

In-phase
Y-Pol.

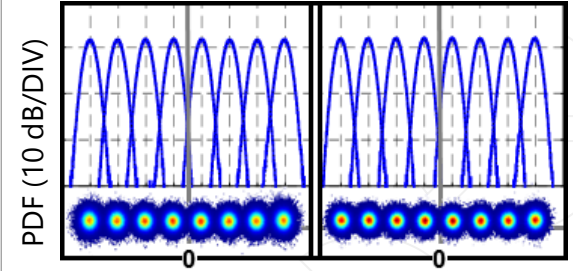
DP-Bi-4ASK



In-phase
X-Pol.

In-phase
Y-Pol.

DP-Bi-8ASK

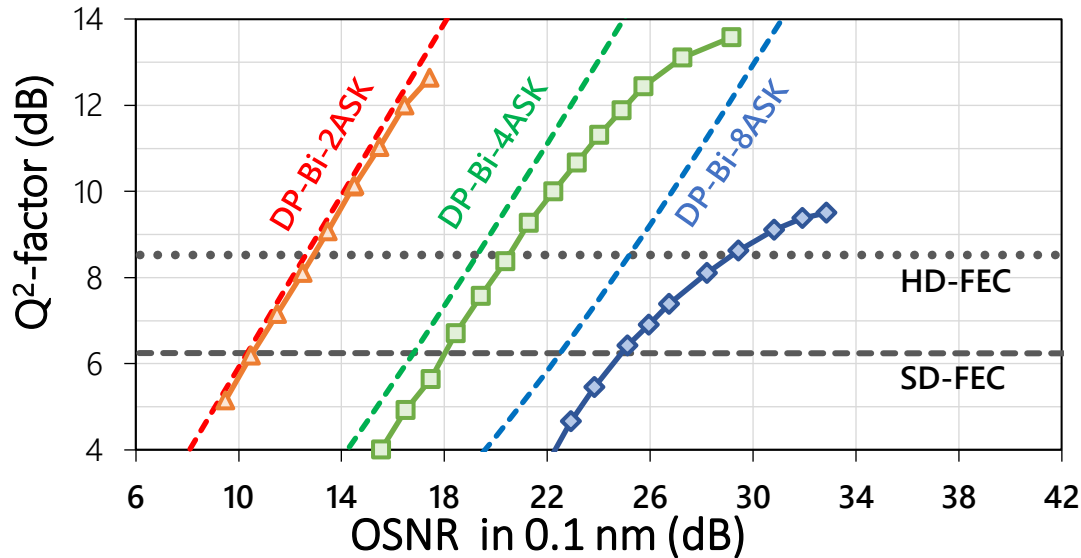


In-phase
X-Pol.

In-phase
Y-Pol.

Clearly separated constellation points for 2ASK and 4ASK

Back-to-back performance



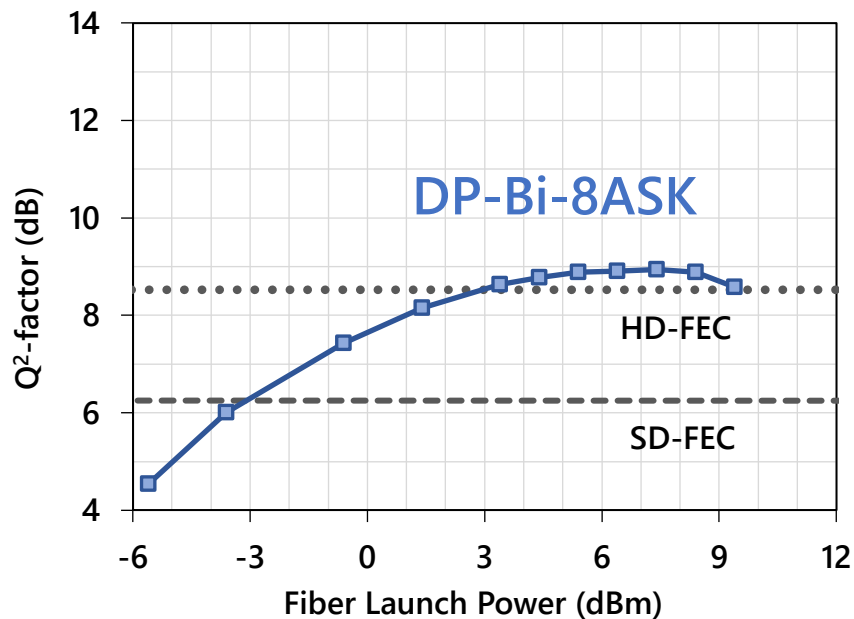
Low implementation penalty for DP-Bi-2ASK and DP-Bi-4ASK

Required OSNR for FEC:

Format	HD-FEC	SD-FEC
DP-Bi-2ASK	13 dB	10.5 dB
DP-Bi-4ASK	20.5 dB	18 dB
DP-Bi-8ASK	29.4 dB	25 dB

Error free transmission for all formats below HD-FEC limit possible, ROSNR < 30 dB

Transmission over 120 km SSMF



Chromatic dispersion eliminated by coherent DSP (standard building blocks)

Optimum launch power ~6 dBm

Error free transmission with HD-FEC and SD-FEC

→ **300 Gbit/s** for SD-FEC
(28% overhead)

→ **342 Gbit/s** for HD-FEC
(12% overhead)

Successful transmission of 342 Gbit/s over 120 km!

Conclusion

Realization of monolithically integrated driver and MZM in 0.25- μm SiGe BiCMOS technology

Generation of dual polarization bipolar mASK signals

Up to 342 Gbit/s (net rate) transmission over 120 km using DP-Bi-8ASK below FEC limit

Promising results for use of the modulator in a nested IQ structure for DP-64QAM!



Thank you

adochhan@advaoptical.com



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