Automatic PMD Compensation at 40 Gbit/s and 80 Gbit/s Using a 3-Dimensional DOP Evaluation for Feedback

- ◆ SOP/DOP-measurement with polarization scrambling

- ◆ No feedback fading due to input-SOP fluctuations

- ◆ PMD compensation at 40 Gbit/s of installed SMF

- ◆ 3-dimensional evaluation yields DGD, PSP, 2nd order PMD

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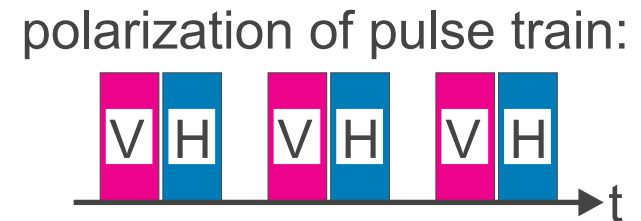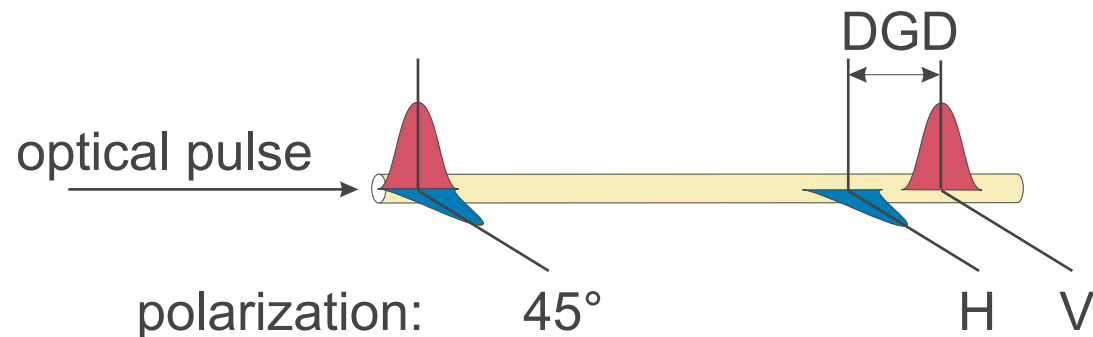Heinrich-Hertz-Institut Berlin

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Degree of Polarization (DOP)

PMD causes partial depolarization:
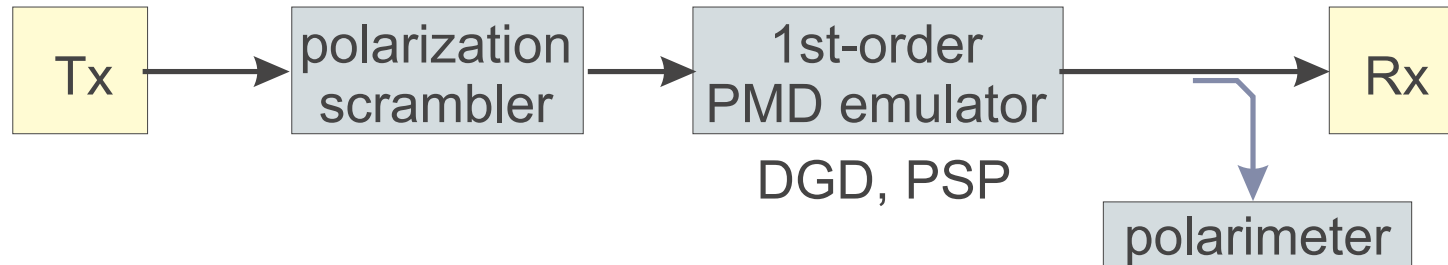
- ♦ decomposition of an optical pulse into two eigenmodes
- ♦ output polarization ' jitters ' $\Rightarrow$ DOP reduction

optical pulse

polarization: 45°   H   V

DGD

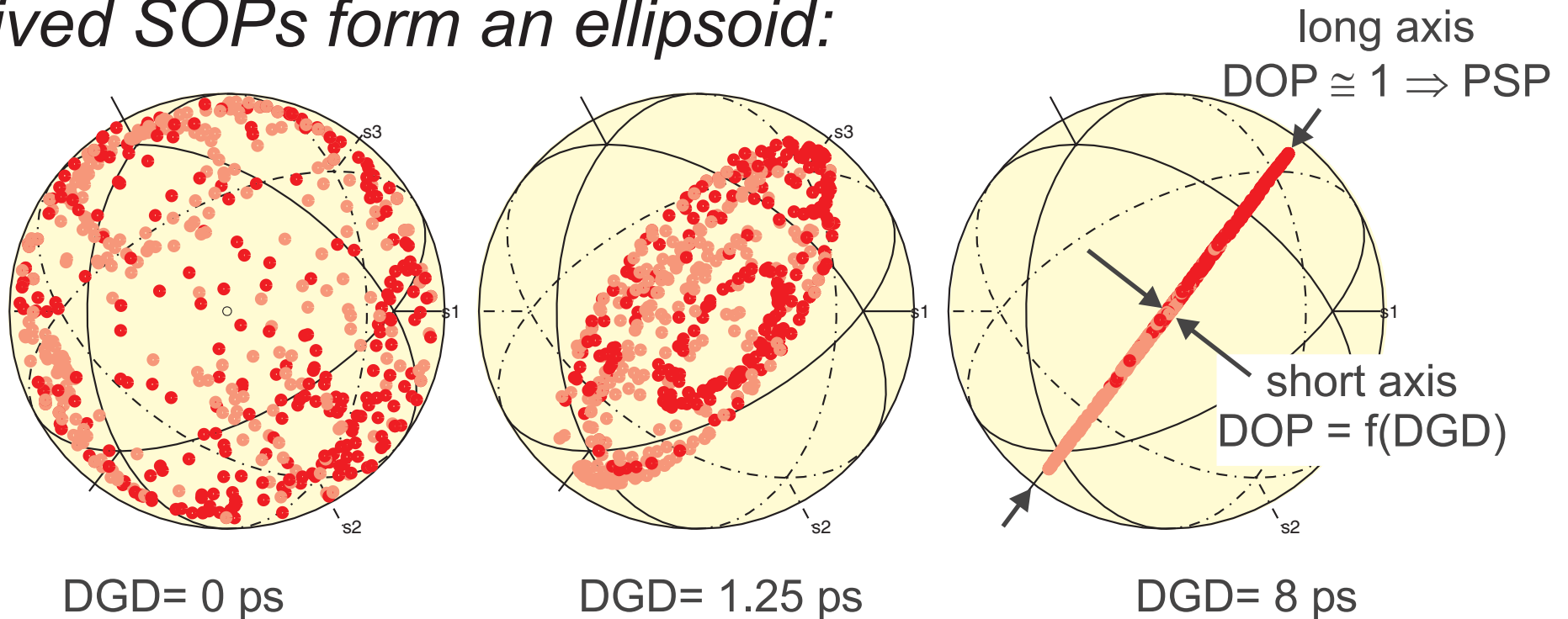polarization of pulse train:

V H V H V H   t

- ♦ DOP depends on DGD and pulse-shape
- ♦ but: DOP also depends on input polarization

$\Rightarrow$ scrambling of input polarization

3-Dimensional DOP-Evaluation
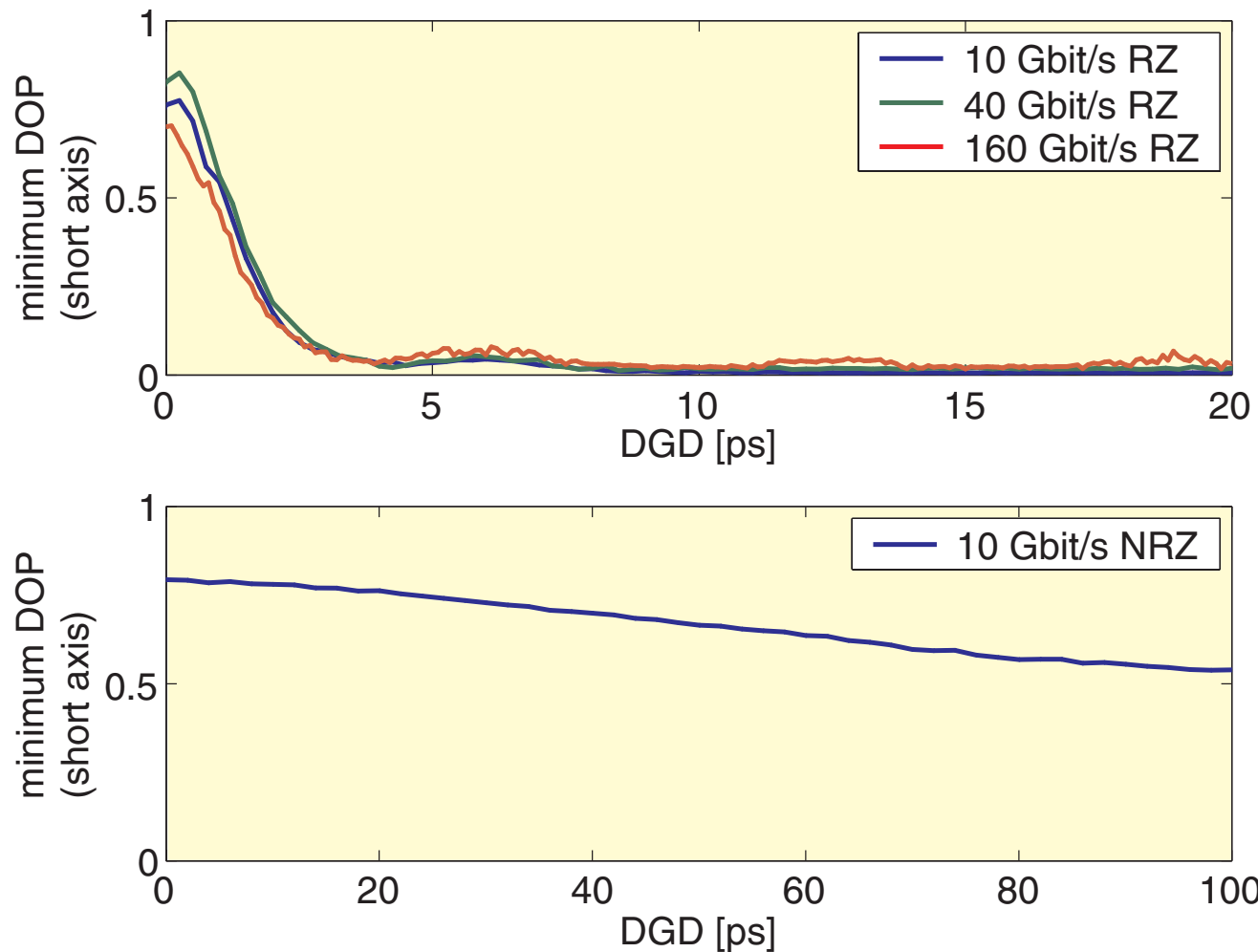
experimental setup at 40 Gbit/s RZ:

Tx → polarization scrambler → 1st-order PMD emulator → Rx

DGD, PSP

polarimeter

received SOPs form an ellipsoid:

long axis
DOP $\cong 1 \Rightarrow$ PSP

short axis
DOP = f(DGD)
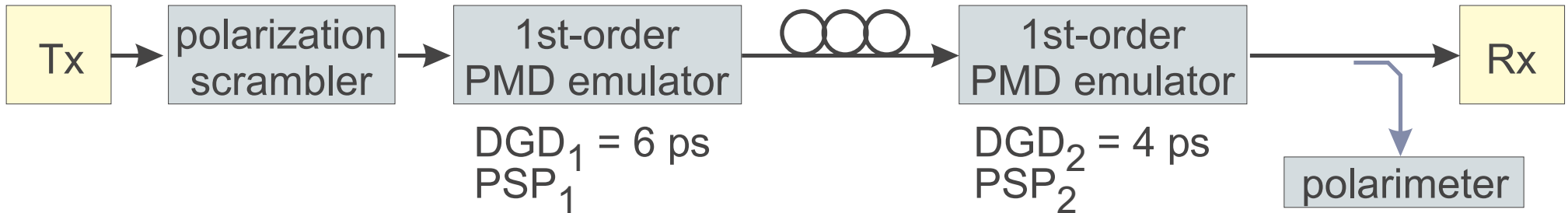
DGD= 0 ps

DGD= 1.25 ps

DGD= 8 ps

DOP Reduction at Different Bit-Rates

sensitivity depends on pulse-shape:

Second-Order PMD

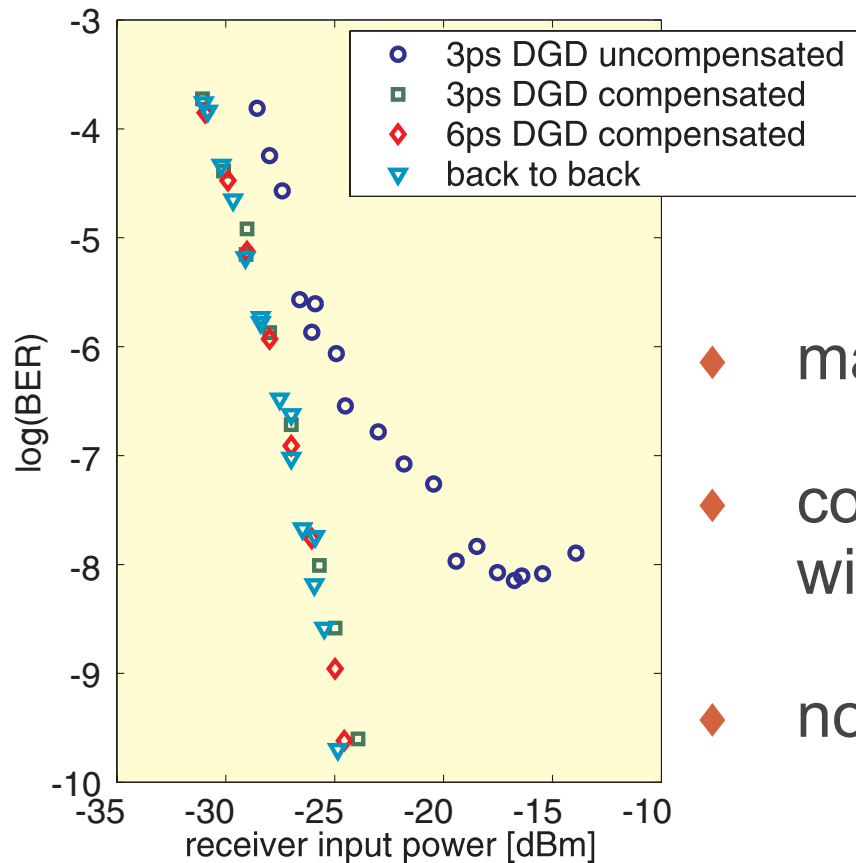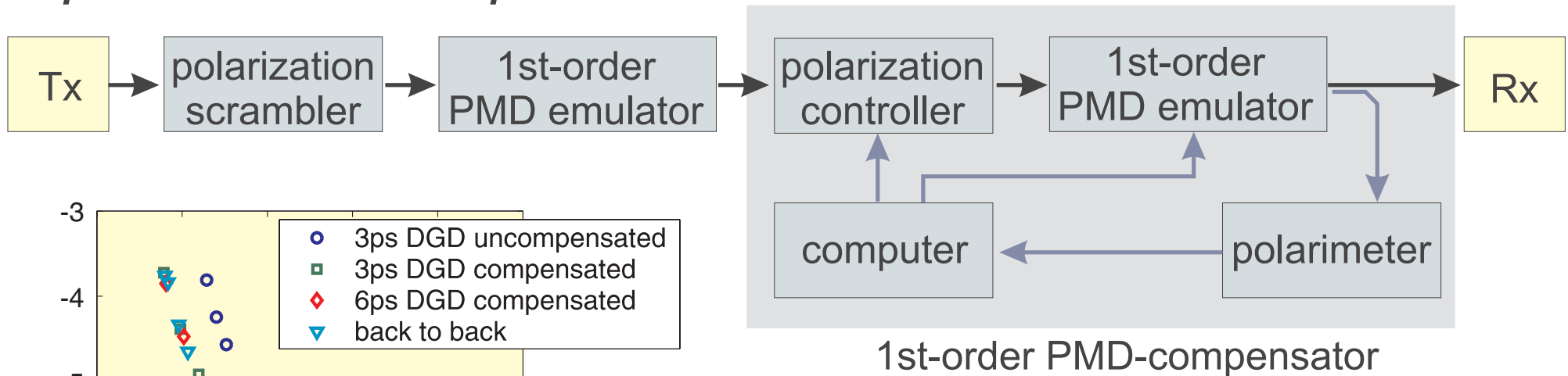## experimental setup at 40 Gbit/s RZ:

Tx → polarization scrambler → 1st-order PMD emulator → ⌒⌒⌒ → 1st-order PMD emulator → Rx

$DGD_1 = 6$ ps
PSP_1

$DGD_2 = 4$ ps
PSP_2

→ polarimeter

reduction of long axis depends on $\angle(PSP_1, PSP_2)$:

DOP = 0.61

s1
s3
s2

DOP = 0.18

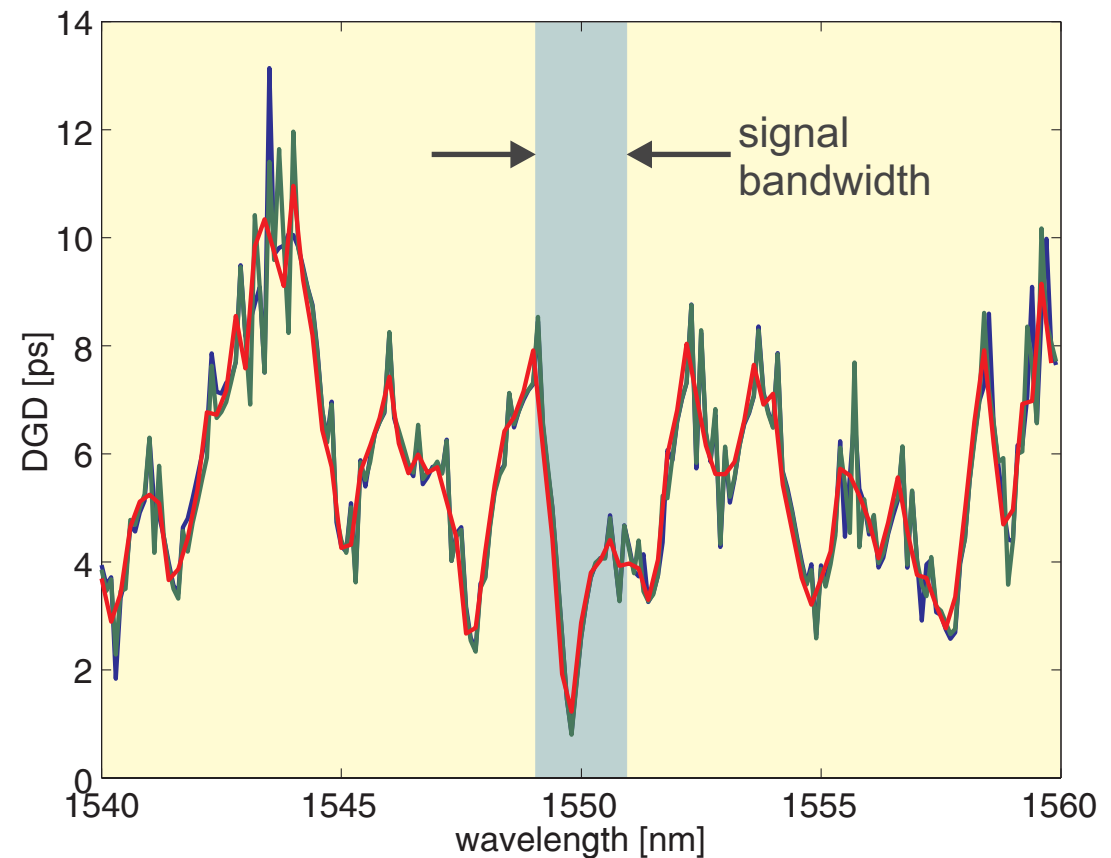s3
s2
s1

Compensation of First-Order Emulator
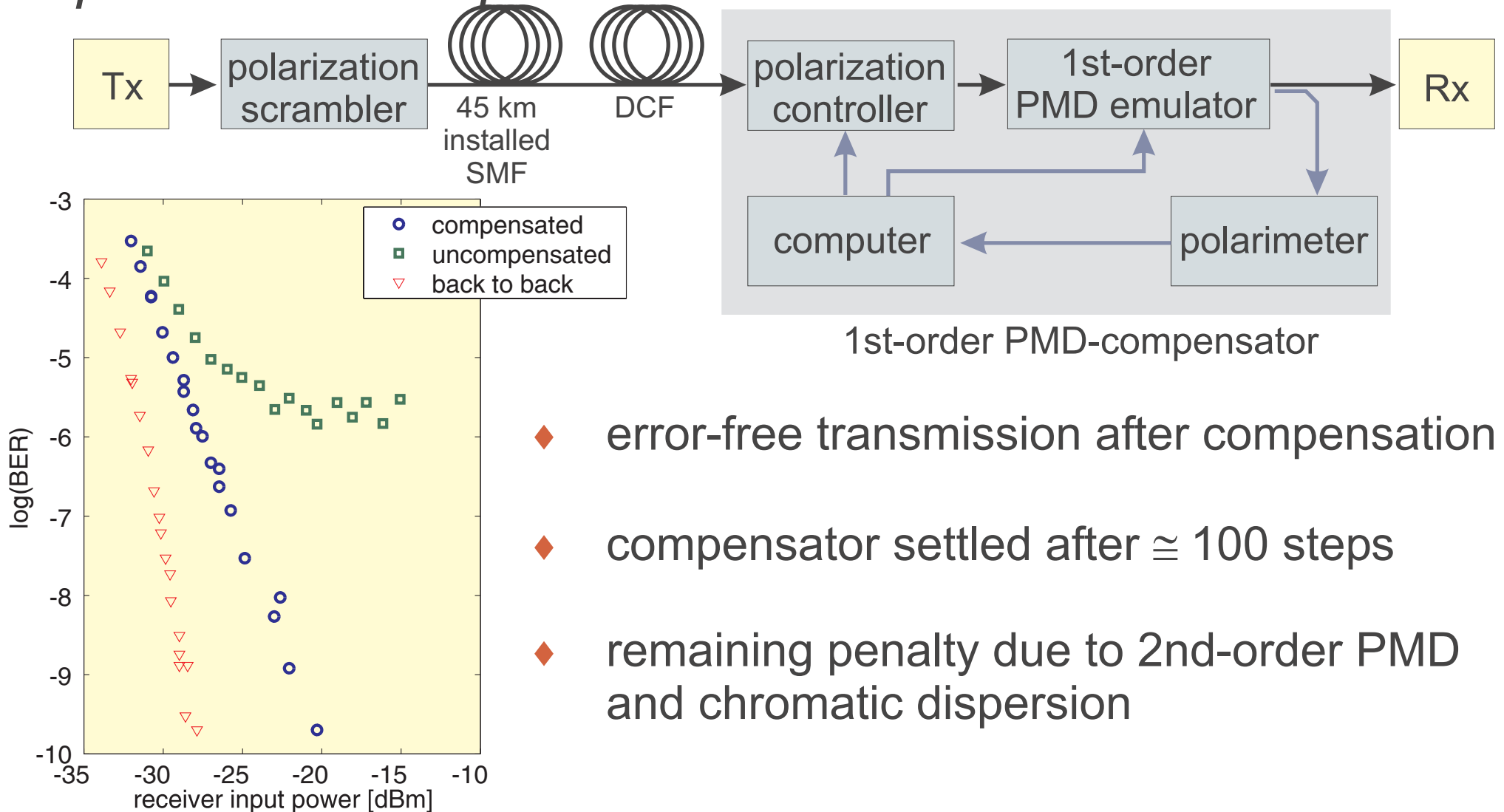
experimental setup at 80 Gbit/s RZ:

- ◆ maximation of the short axis of the ellipsoid

- ◆ compensator matched emulator DGD with accuracy of 0.2 ps (80 Gbit/s RZ)

- ◆ no penalty after compensation

Field Experiment

- ◆ 45 km Installed SMF in the city of Berlin
- ◆ PMD measurements at different times: <DGD> $\cong$ 6 ps
- ◆ second-order effects within signal bandwidth

Field Experiment

experimental setup at 40 Gbit/s RZ:

1st-order PMD-compensator

- ◆ error-free transmission after compensation

- ◆ compensator settled after $\cong$ 100 steps

- ◆ remaining penalty due to 2nd-order PMD and chromatic dispersion

Conclusions

- field-experiment: PMD compensation at 40 Gbit/s over 45 km SMF

- lab-experiment: PMD compensation of an emulator at 80 Gbit/s

- polarization scrambling + DOP measurement :

  $\Rightarrow$ no dependence on input polarization $\Rightarrow$ no feedback fading

  $\Rightarrow$ works for RZ/NRZ and bit-rates >> 40Gbit/s

  $\Rightarrow$ no high-speed electronics

  $\Rightarrow$ higher sensitivity for shorter pulses

  $\Rightarrow$ 3D-evaluation yields DGD, PSP and 2nd-order PMD