your innovative fiber optics provider

FIBERPRO

All Fiber Polarization Scrambler

Your Solution for Polarization related Problems

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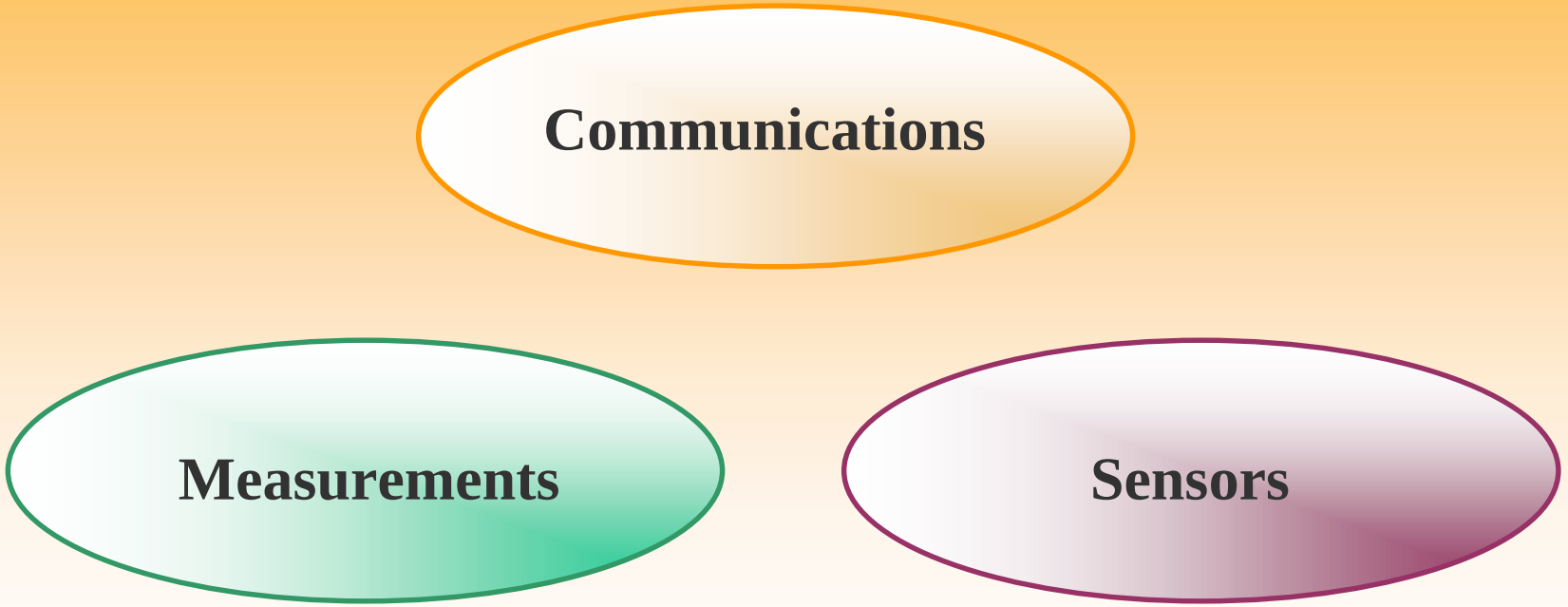
FiberPro Lab.

Contents

Why PS?

To solve the polarization-related problems in,



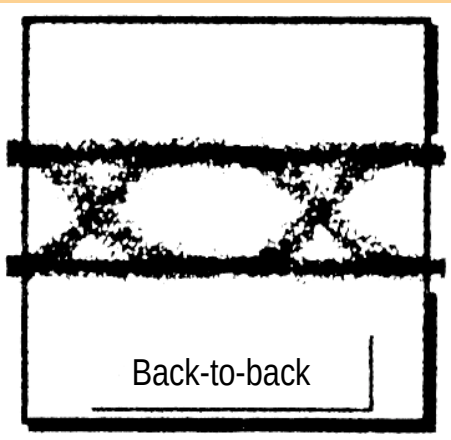
Limiting Factors in Amplified systems Cumulati ve Signal distortions

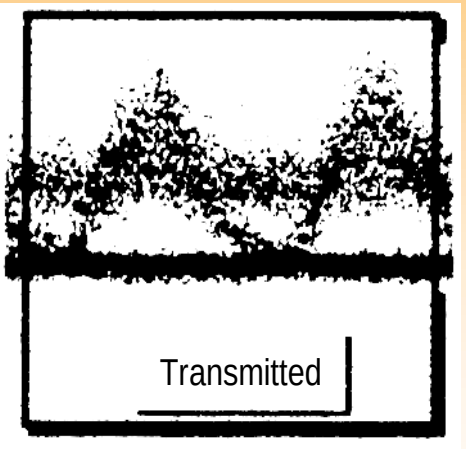
Polarization effects

Polarization mode dispersion (PMD) •Temporal pulse broadening

Polarization Dependent Loss (PDL) •SNR fluctuations

Polarization Dependent Gain (PDG) •SNR average penalty

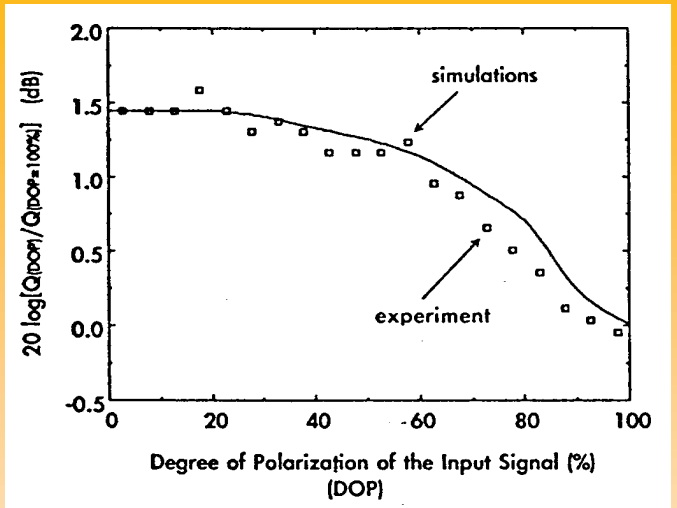




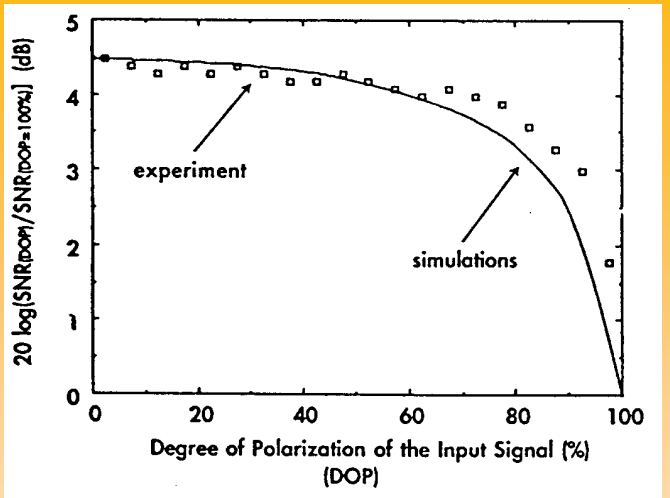
1000km span, Including CD, Nonlinear effect

J. Chesnoy, Alcatel, ECOC'97

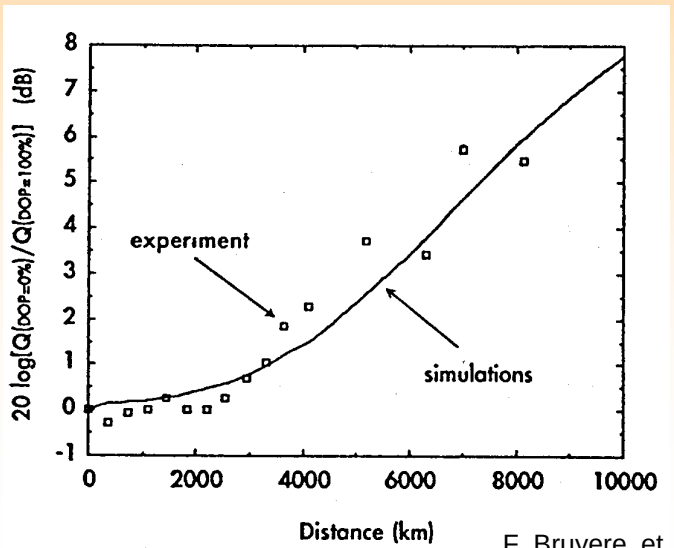
Polarization effect in long haul systems



Mean penalty on the Q factor in a 4000km link



Mean penalty on the SNR in a 4000km link



Improvement in the mean Q due to polariation scrambling vs. link length. at DOP < 10%

Simulation parameters
PDG =0.14dB/EDFA
PDL =0.06dB/EDFA
PMD =0.13ps/sqrt(km)

Experimental parameters
1kHz scrambling speed
Single source(1558.6nm)
5Gbps, NRZ
with 181 EDFA, 4000km link

F. Bruyere, et. al., IEEE Photo. Technol. Lett., Vol. 6, No. 9, 1153 (1994)

Polarization Problems in Measurement

- Example 1.

  In long-haul DWDM system, **Gain-Wavelength characteristics** nee d to be tested **precisely up to 0.005 - 0.01 dB**

  For equalization and etc.

  ⇨ **Input Light Power fluctuation by PDL**

  ⇨ **Output Power fluctuation by PDG (~0.1dB)**

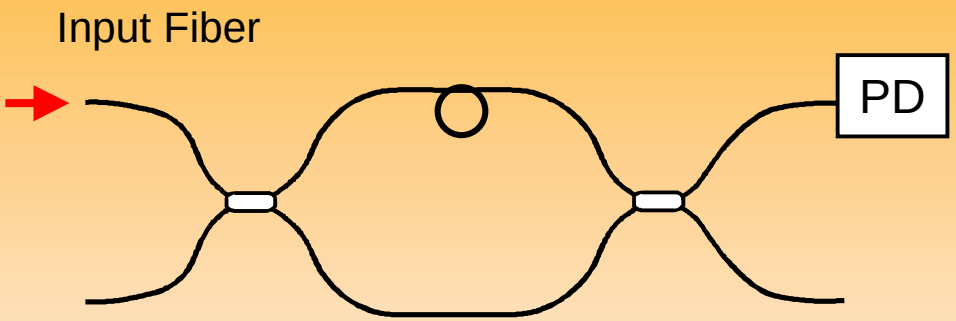
  ⇨ **PDL in measurement equipment (0.03-0.1dB)**

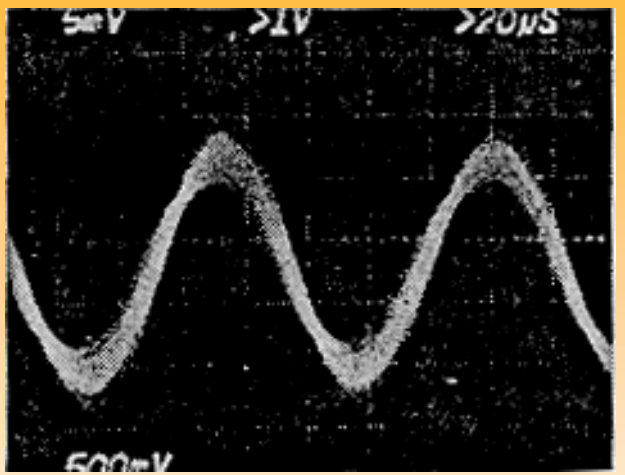
- Example 2.

  Filters for telecommunications requires to set accurately less than 10G Hz(0.08nm). PDL can give wrong value of **center wavelength** during i nterrogation.

Polarization-Induced Phase Noise in Fiber Interferometric Sensors

Mach-Zehnder Interferometer





- Polarization Perturbations of Input Fiber
  - ⇨ **Visibility fluctuation**
  - ⇨ **Phase Noise**

Polarization Scrambling can

solve the polarization-related problems in,

Communications
- PDG in long EDFA chain

Measurement
- Error caused by PDL of DUT & Measuring equipment

Sensors
- Polarization induced phase noise

What is polarization scrambling?

A. Depolarizer:

Removing correlation betwe en polarization states

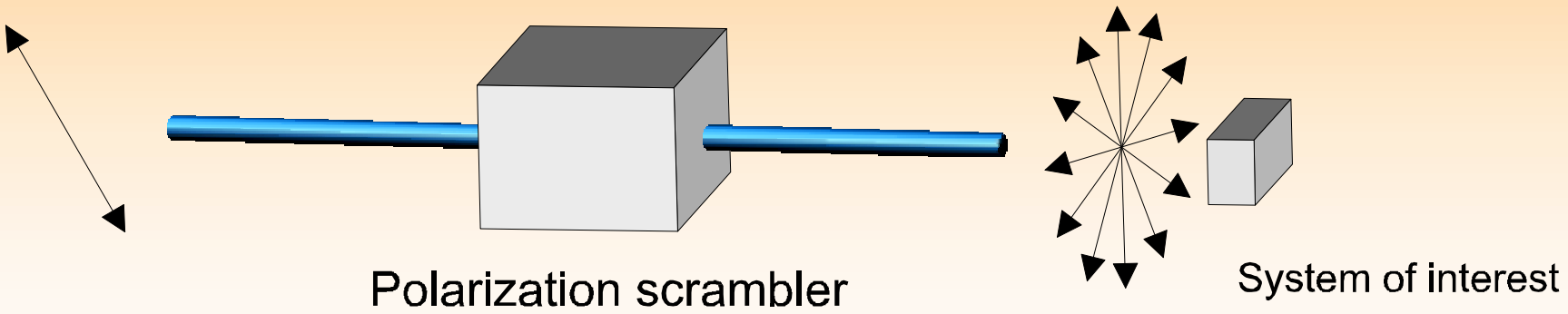
(Broadband Source)

e.g.: Lyot depolarizer

B. Polarization Scrambler:

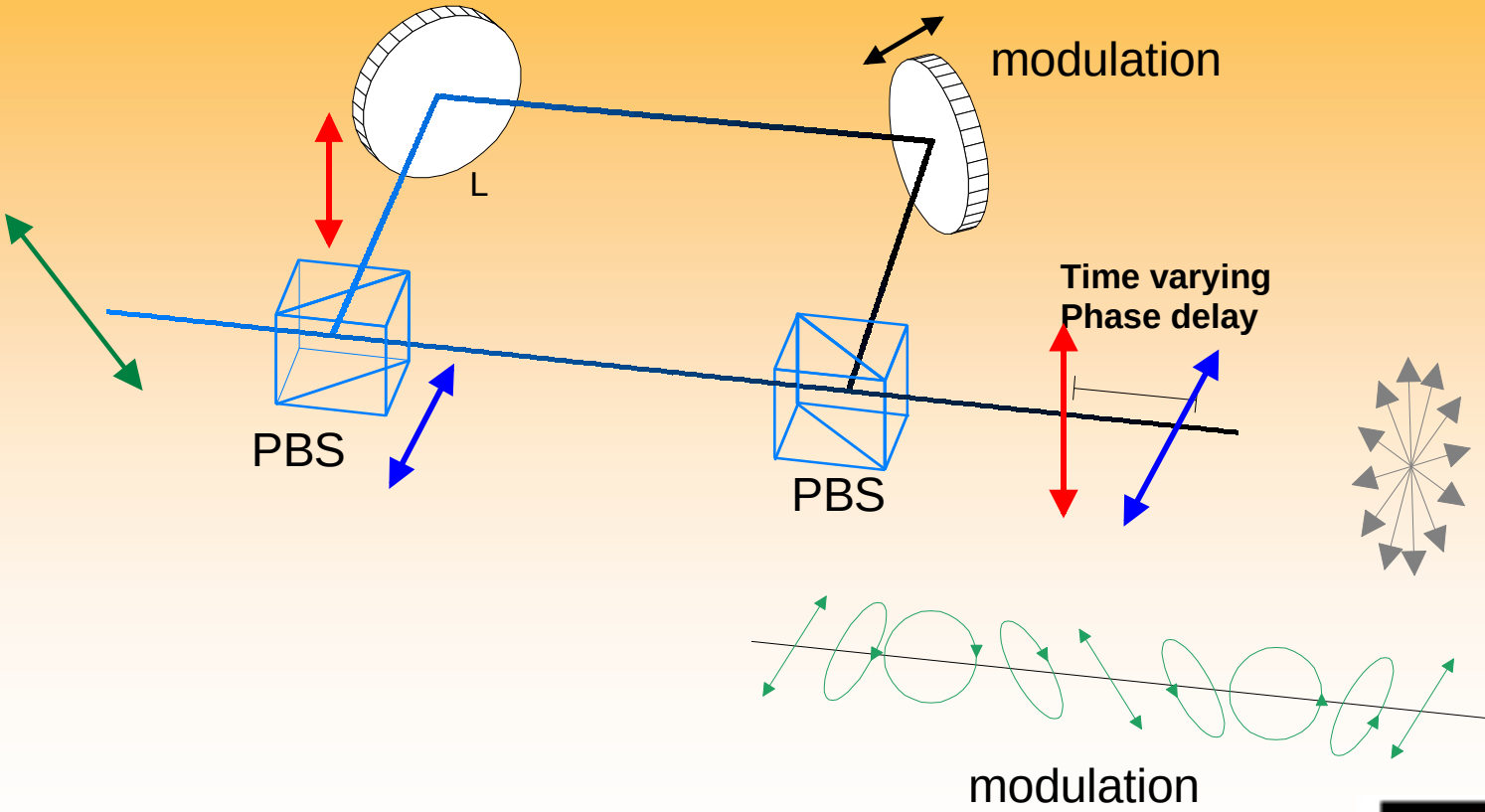
Modulate polarization state (over Poincare sphere)

(Monochromatic Source)



How to make polarization scrambling?

Concept : Apply time varying phase delay between the two orthogonal polarization modes.



Principle of Polarization Scrambling

Monochromatic light

$$\begin{cases} E_x(t) = a_1 \exp[\, i\varphi_1(t)\,] \\ E_y(t) = a_2 \exp[\, i\varphi_2(t)\,] \end{cases} \qquad \delta = \varphi_1 - \varphi_2$$

General Stokes Parameters

$$S_0 = \langle a_1^2 \rangle + \langle a_2^2 \rangle$$
$$S_1 = \langle a_1^2 \rangle - \langle a_2^2 \rangle$$
$$S_2 = 2 \langle a_1 a_2 \cos\delta \rangle$$
$$S_3 = 2 \langle a_1 a_2 \sin\delta \rangle$$

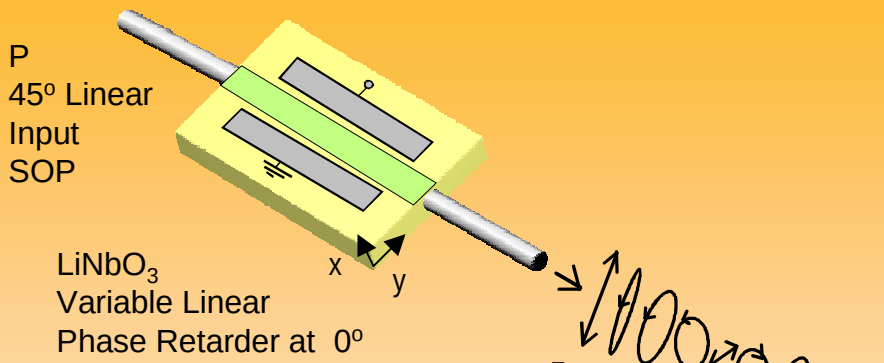
Effective Degree of Polarization

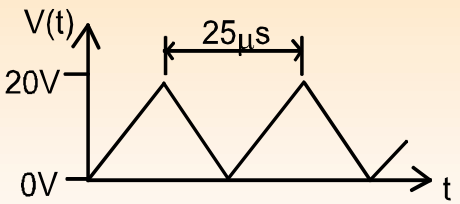
$$P_{eff.} = I_{pol.} / I_{tot.} = \mathrm{sqrt}(S_1^2 + S_2^2 + S_3^2) / S_0 \quad (0 < P_{eff} < 1)$$

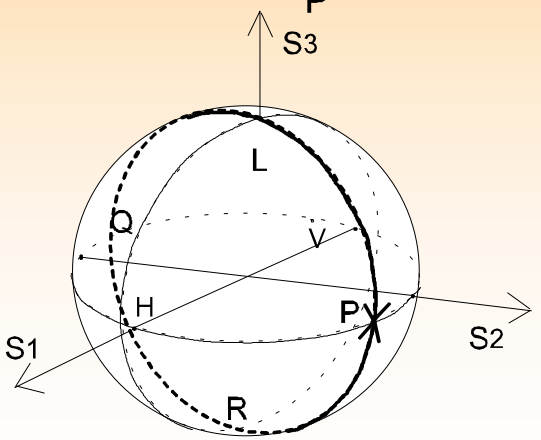
Effectively Depolarized Light (Perfectly Scrambled Light)

$$P_{eff.} = 0$$

Electro-Optic Polarization Scramblers



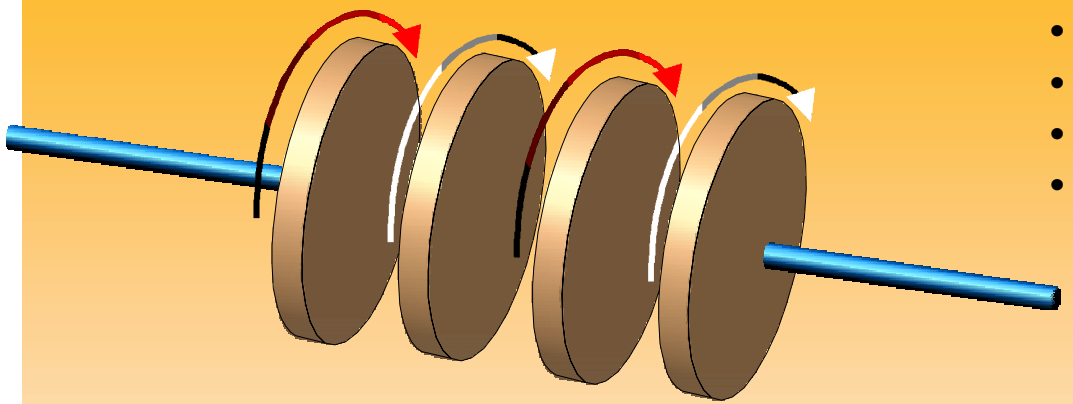




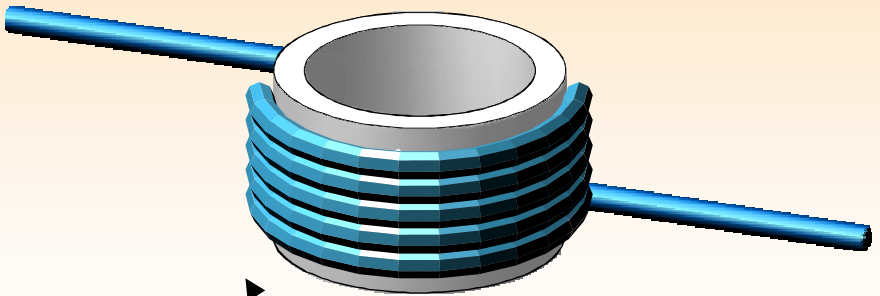
- **Fast Speed.**
- **Relatively small**
- **Phase chirp**
- **High PMD: ~ 17 ps**
- **Complex driving circuit**
- **High loss: > 5 dB**
- **Input Pol. Dependent**

$$\Delta\varphi(t) = \Gamma_y (2\pi/\lambda_0)\, n_0^3 r_{12}\, L\, (V(t)/G) \propto 1/\lambda^2$$

Mechanical/PM fiber Polarization scramblers



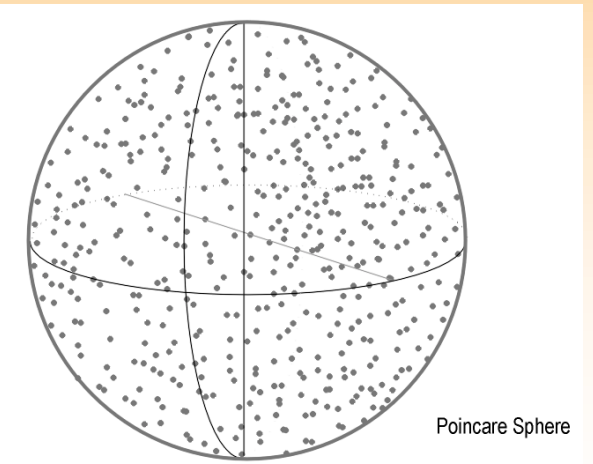
Rotating waveplate



PM fiber

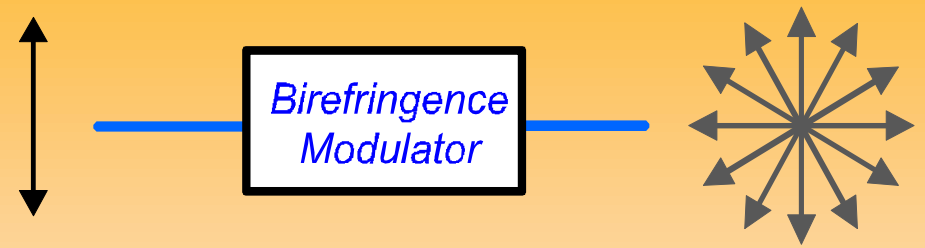
- **Pseudo Random Pol. generation**
- **Slow speed: ~100 rev./sec MAX**
- **Not for DOP zero applications**
- **High PMD (PM fiber type)**

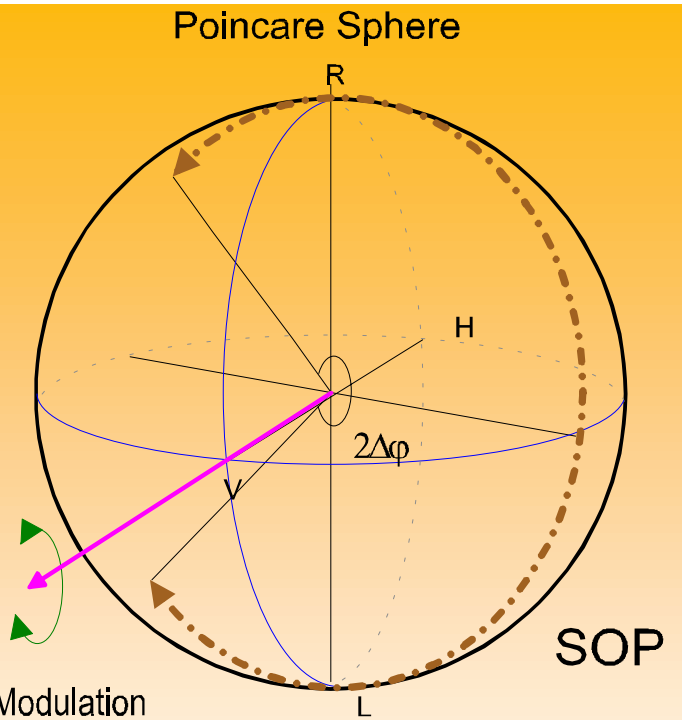
Trace for 2 second



Poincare Sphere

Polarization scrambling at PS





Sinusoidal Modulation
of Birefringence

Input polarization i
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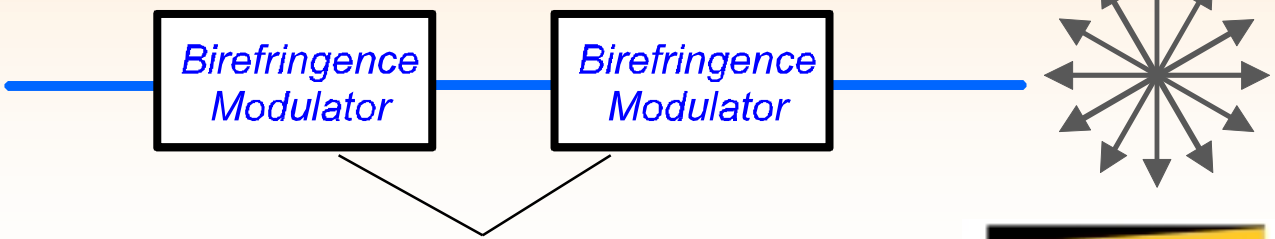
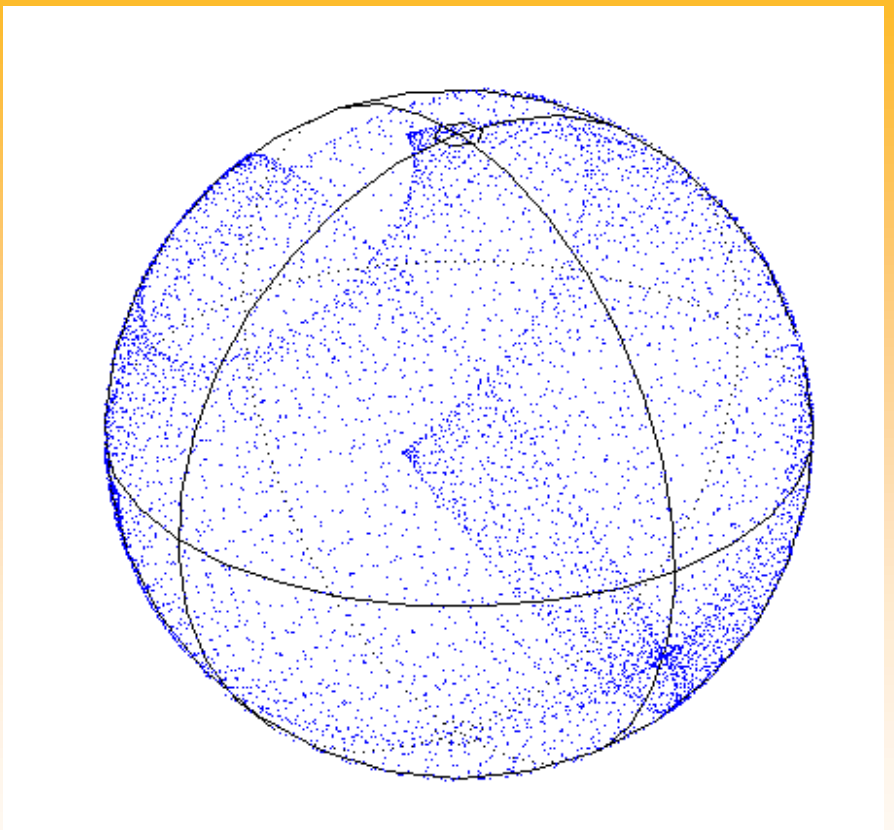
Polarization scra
mbling



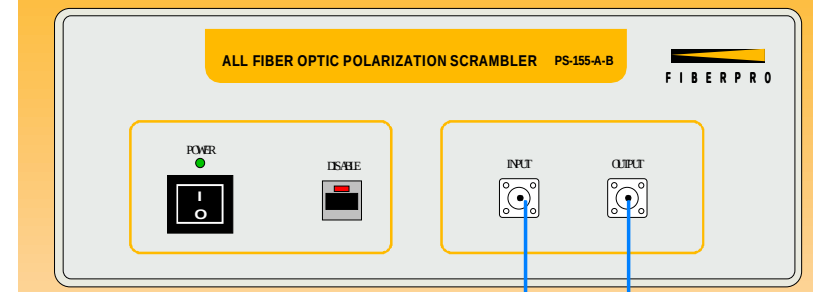
For orthogonal polarization

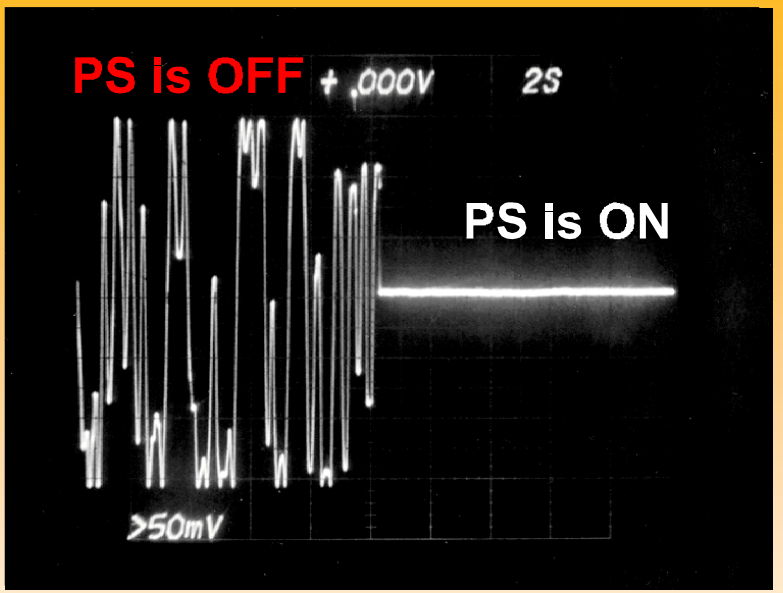
Poincare Sphere representation of Output SOP



Trace for 200 μsec

Polarization Scrambler Output





Input Polarization State

Output Polarization State

Polarized Source

Polarization Controller

Polarization Controller

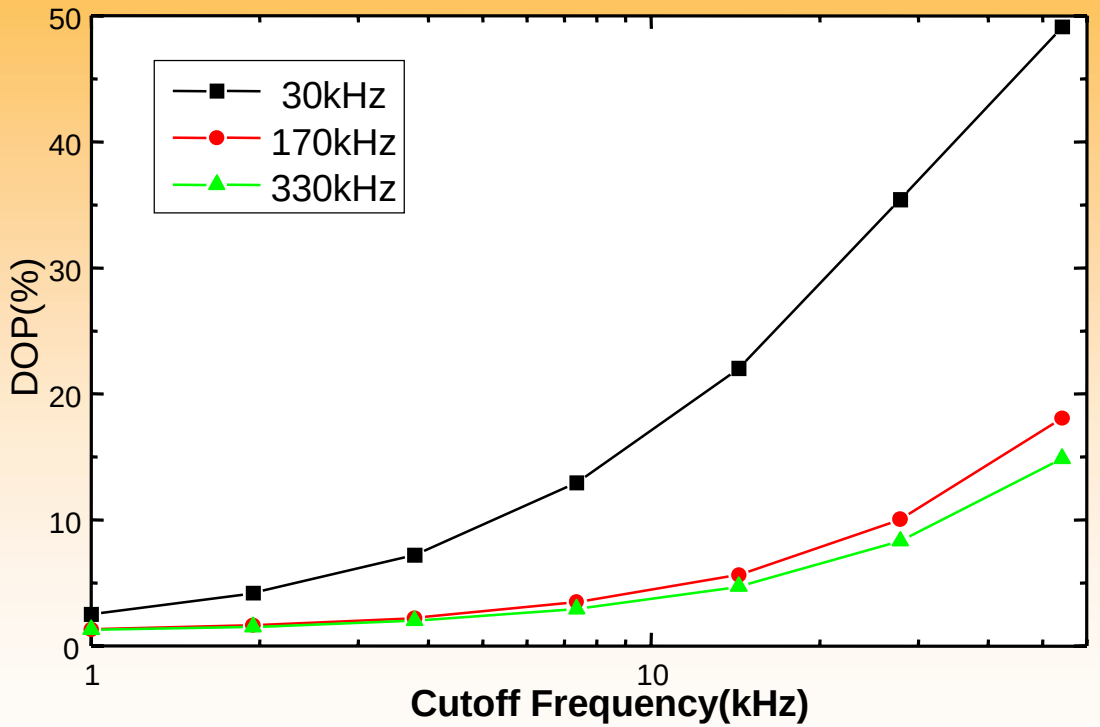
Polarizer

Receiver

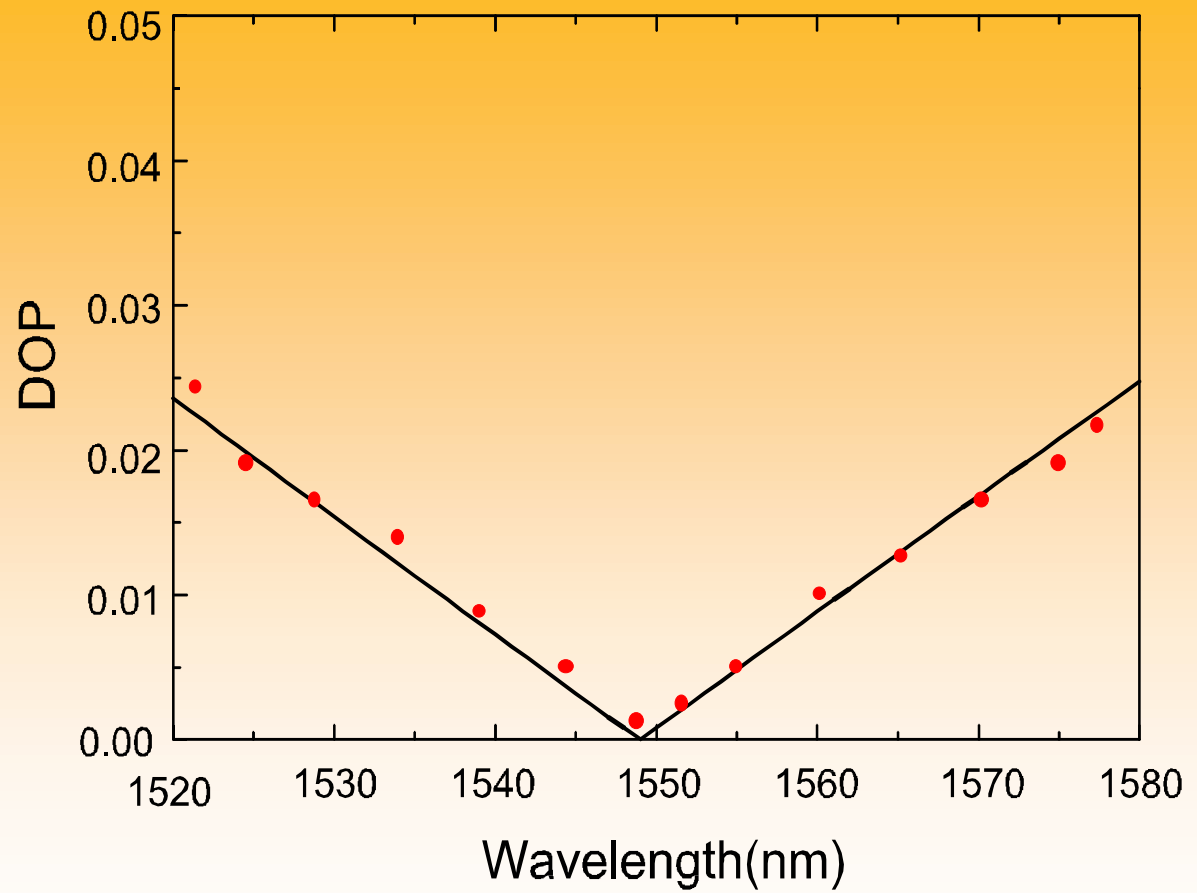
Input Polarization Independent

Output DOP vs. Measurement Bandwidth

- PS makes Zero DOP on time average.
- Measurement bandwidth is important parameter when using PS.



DOP vs. Wavelength (center: 1549 nm)



FIBERPRO. S All Fiber Optic Polarization Scrambler

PS for Rack mount(custom made)

Why FiberPro. s PS?

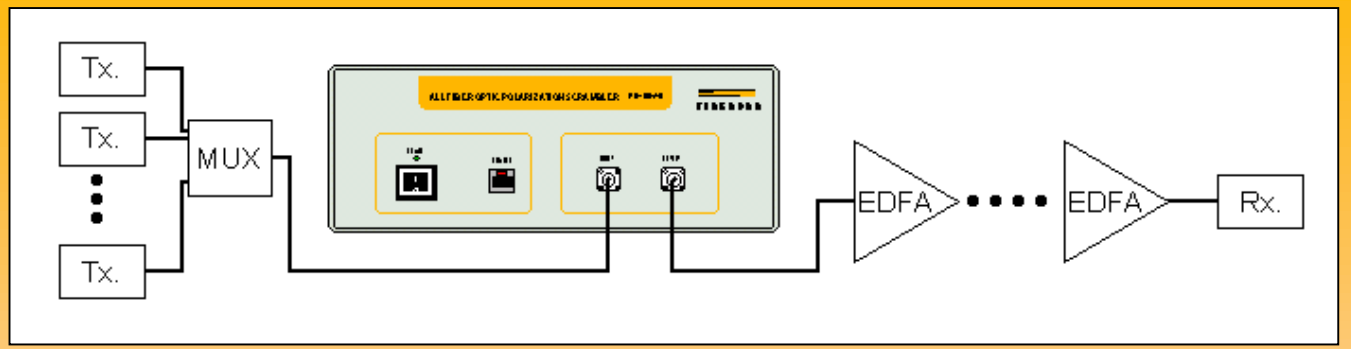
- **All Single Mode Fiber configuration**
- **Low Loss < 1.5dB (with connectors)**
- **Super Low PMD < 0.2 psec**
- **High Speed**
- **Wide operating Wavelength Range: > 60nm**
- **Plug & Play**

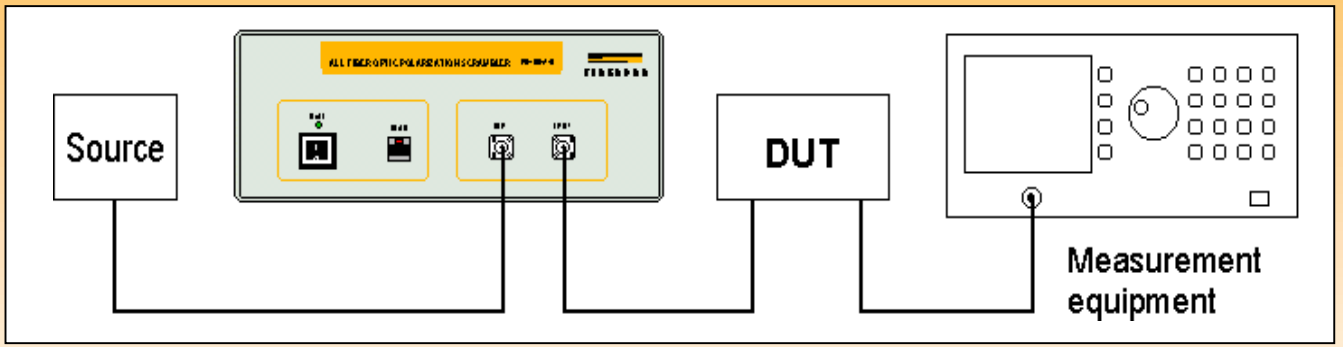
Typical applications of PS

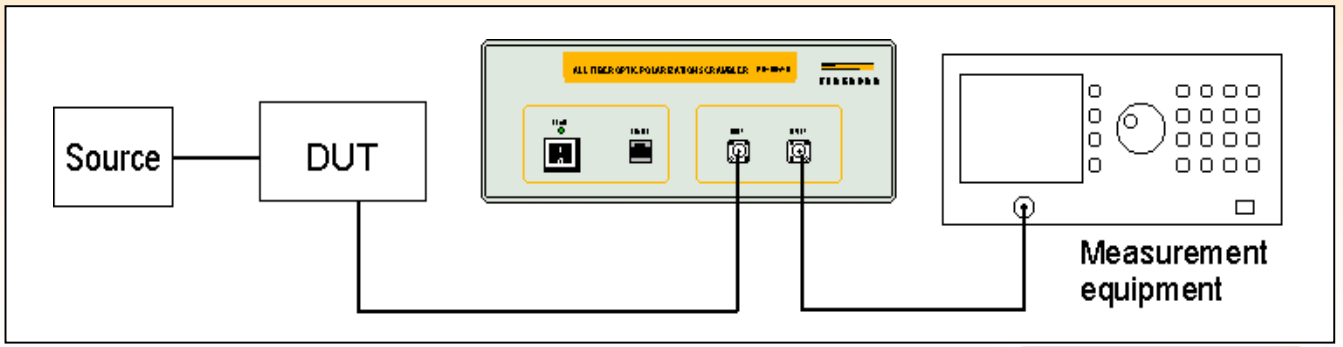
- Improving SNR from PDG, Pump Pol. Dep. in long-haul systems

- PDL independent m easurement. Filter, E DFA, and etc.

- Removing error fr om equipment. s P DL

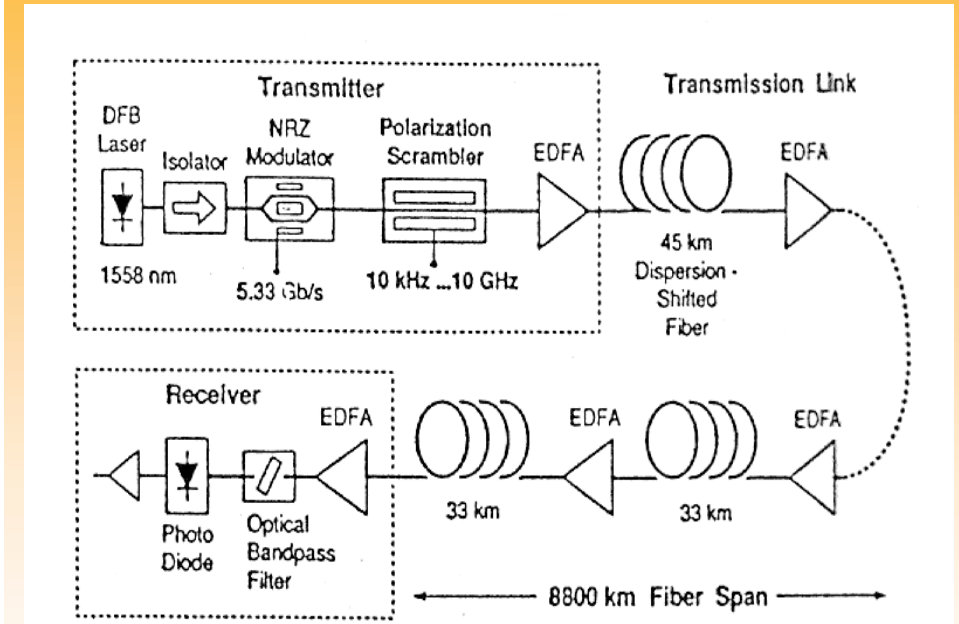




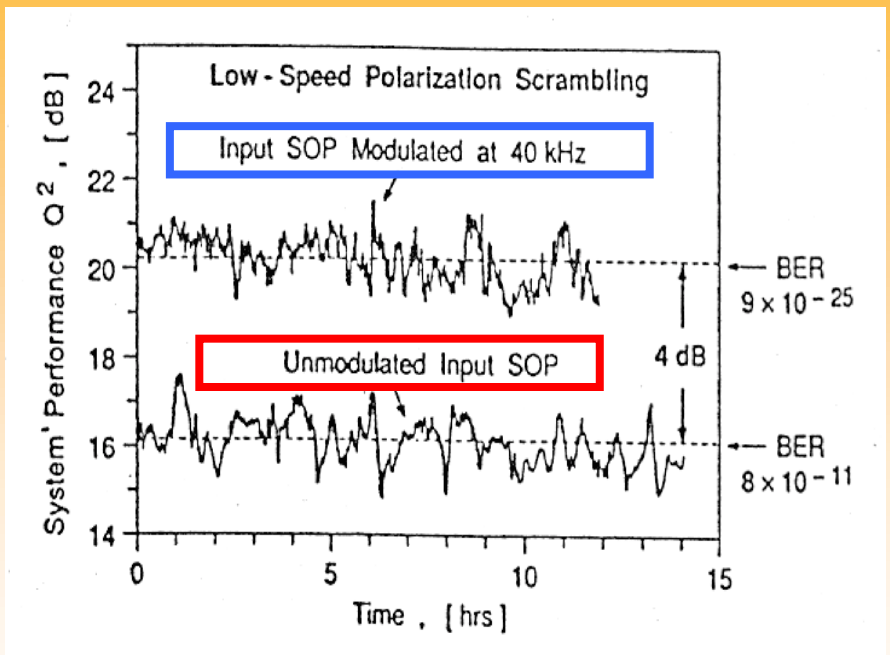


BER Improvement in Long-haul Transmission: Single channel

Set-up ~9000 km transmission

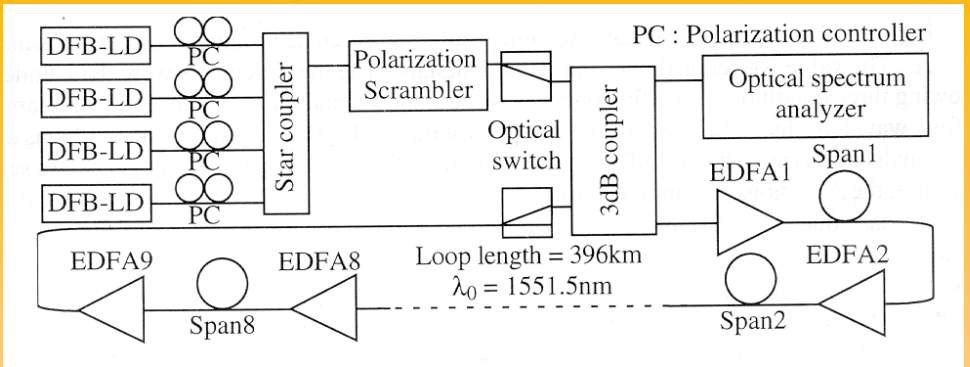


BER after transmission

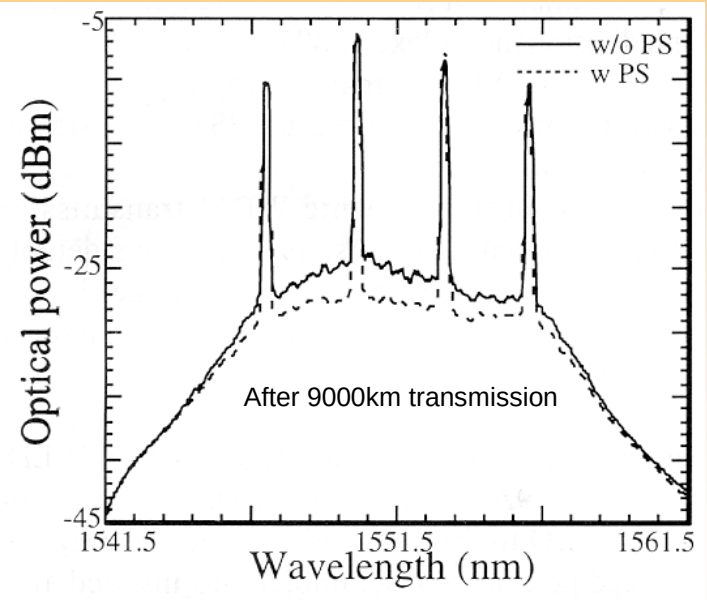


F. Heismann, et. al., PTL, Vol. 6, No. 9, 1156 (1994)

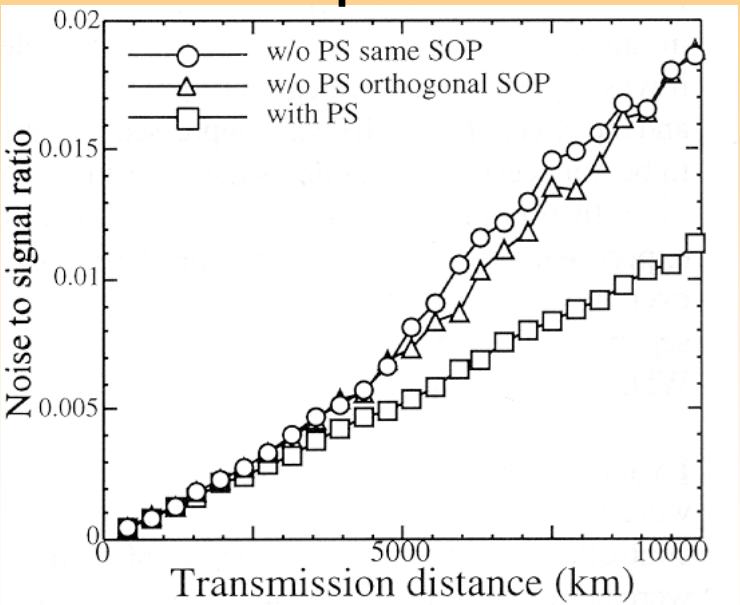
SNR Improvement in Long-haul Transmission: Multi channel



Reduce accumulated ASE noise

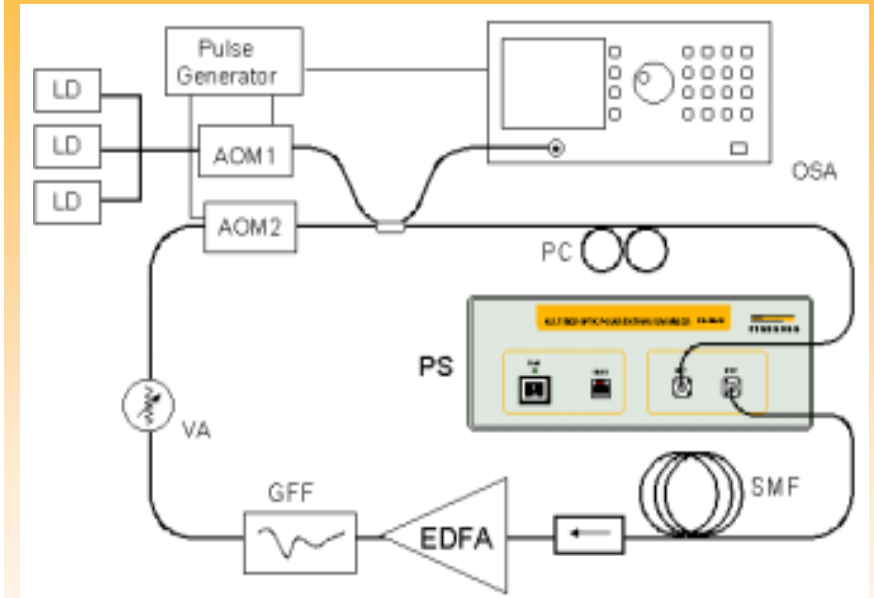


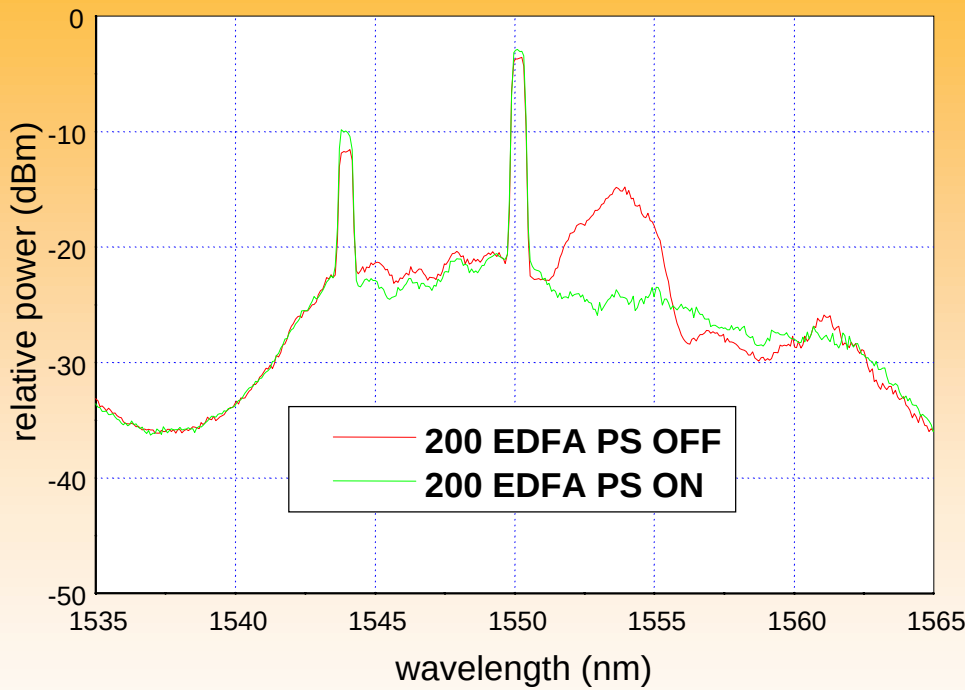
SNR improvement



H. Taga, et.al., WE6-1, OFC. 99 Technical Digest (1999)

Accumulated PDG/PDL in long EDFA chain



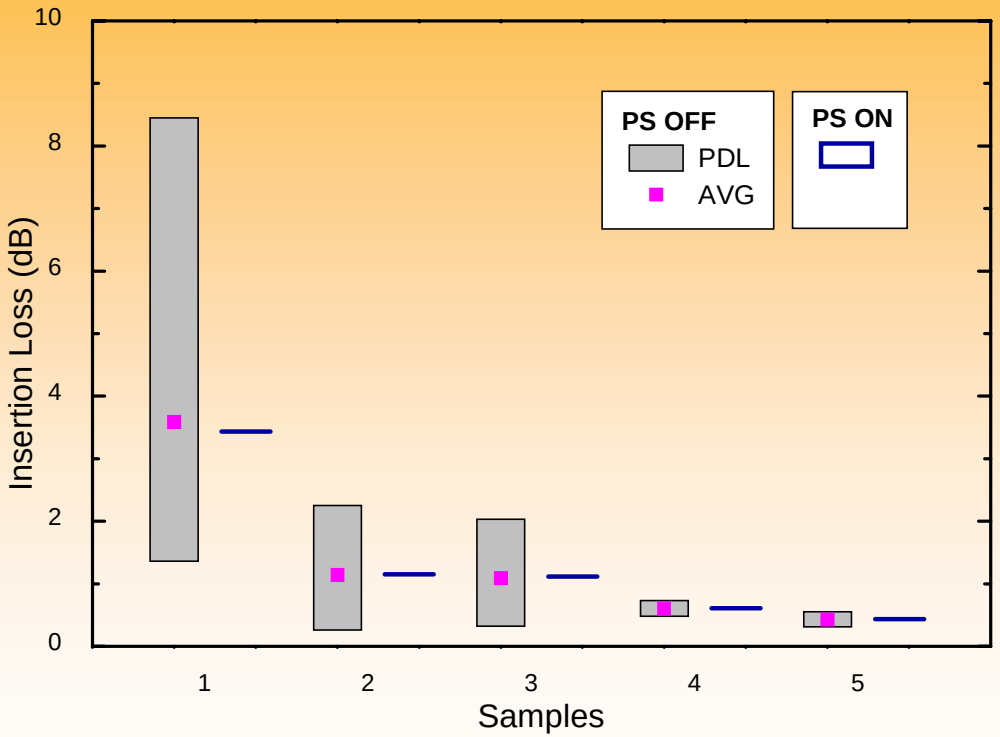


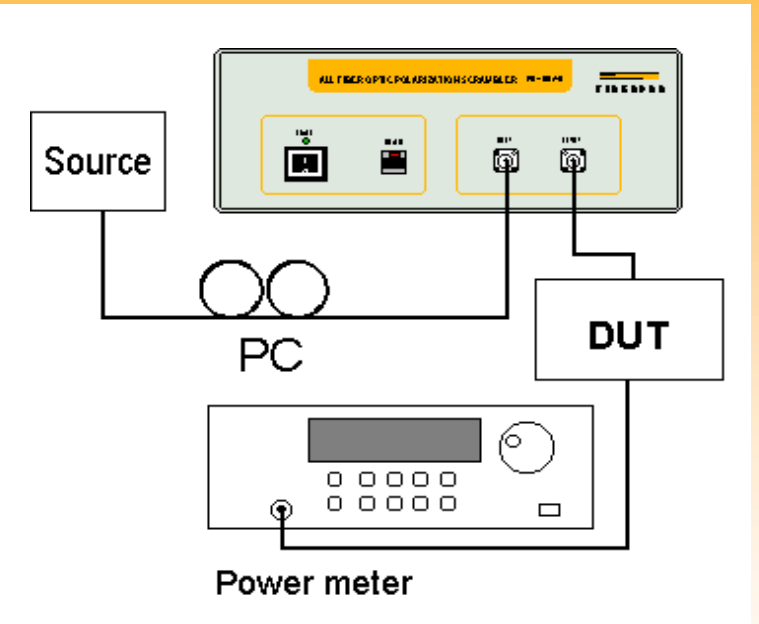
LD: Laser Diode
VA: Variable Attenuator
AOM: Acousto-Optic Modulator
PC: Polarization Controller
GFF: Gain Flattening Filter

H.S. Cheong, et. al., Elect. Lett., Vol.34, 2045 (1998)

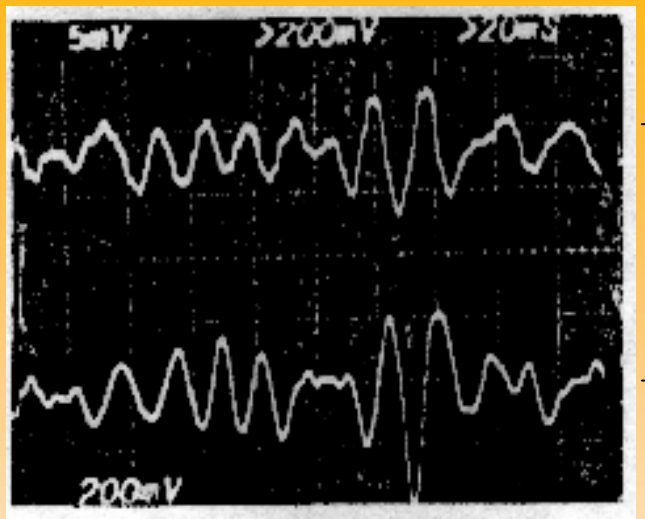
IL Interrogation of DUT with PDL

PDL in the DUT can make erroneous values in measuring IL and etc.



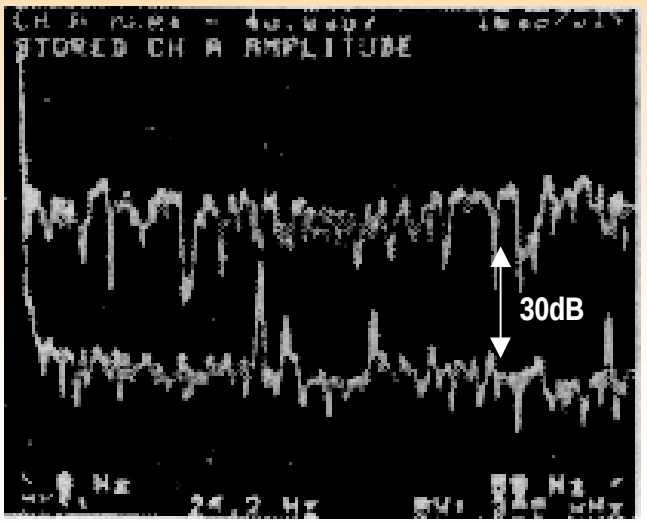


Polarization Induced Phase noise



→ Polarization induced noise

→ Interferometer output



→ Noise floor when scrambler Off

→ Noise floor when scrambler ON

A. D. Kersey, et. Al., JLT, Vol. 8, No. 6, 838 (1990)

other applications...

- **Pump Polarization Dependent Gain in EDFA**

  1480 nm, 980nm version is available

  other wavelengths are also available.

- **Polarization modulator applications**

  sensors, lasers, and etc.

- **Polarization Dependent Loss measurement**

  PDL Multimeter under development

Conclusions

All Fiber Polarization Scrambler

- **Solves PDG/PHB** in long-haul systems.
- **Component characterization** without polari zation dependence.
- **Manufacturing** filters or WDM component.
- **Removes Polarization induced phase noi se or errors** in Fiber Interferometers
- **Polarization Simulation.**

Future works

Fast PDL measurement