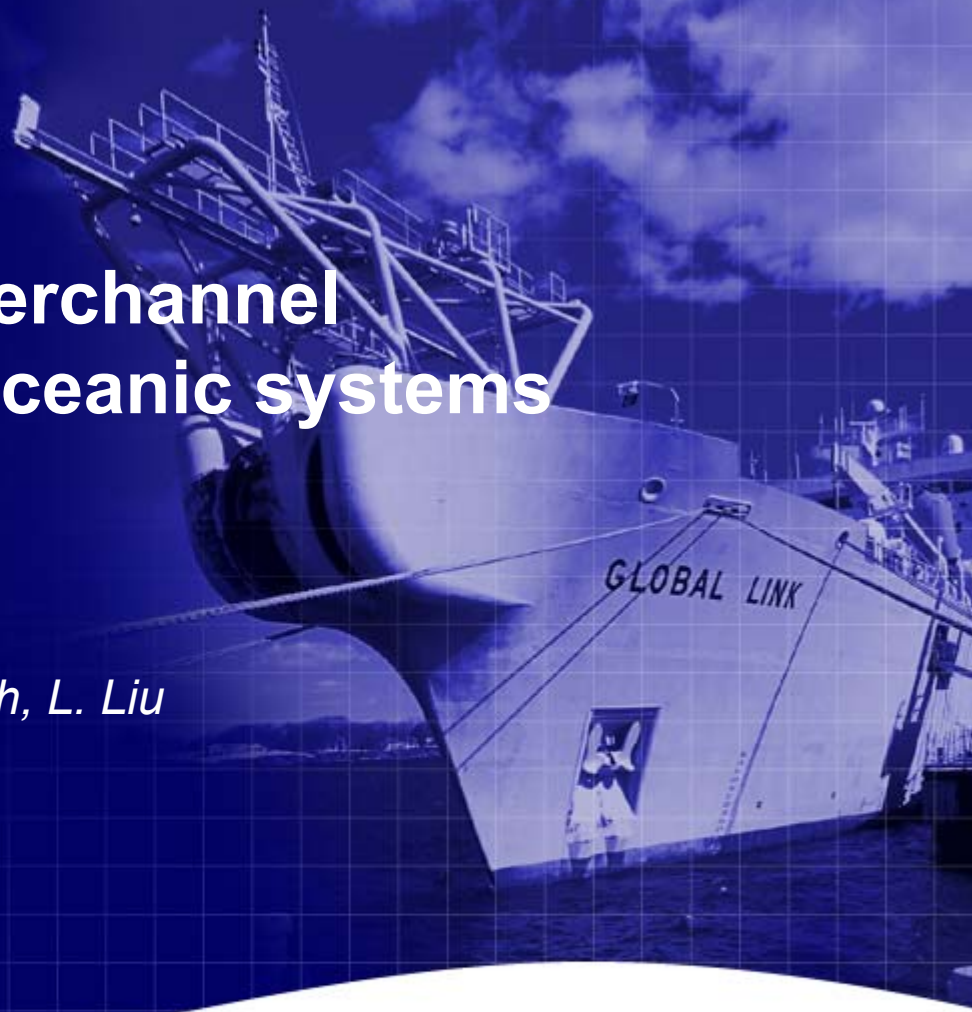
Enabling technology for suppressing nonlinear interchannel crosstalk in DWDM transoceanic systems



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Telecommunications

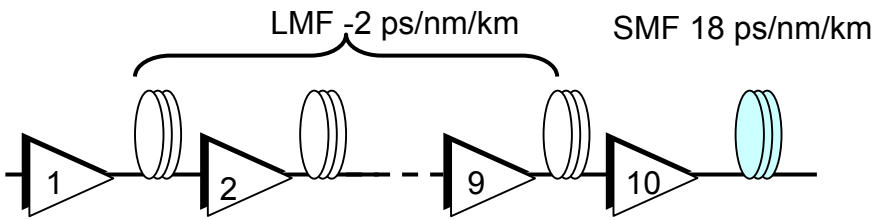
Main topics

- Reducing nonlinear inter-channel crosstalk techniques
- Orthogonal launch

Techniques for reducing nonlinear interchannel crosstalk

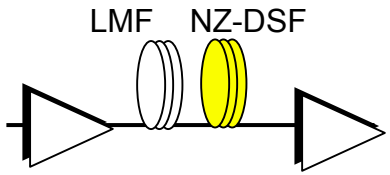
1. Large effective area transmission fibers
   - Nonlinear phase shift is inversely proportional to Aeff
   - Unfortunately, large Aeff fiber has a large dispersion slope to > 0.1ps/nm^2/km

2. Standard dispersion management
   - Reducing XPM effect by avoiding propagating over zero-dispersion wavelength
   - Reducing FWM effect by reducing phase-matching length
   - However, Have non-zero dispersion slope, and interaction between large accumulated dispersion and nonlinear effects results in signal distortion in edge channels



3. Modern dispersion management

– Combination of Large-Mode (LMF) and Non-Zero Dispersion shifted fiber (NZ-DSF) reduces overall dispersion slope to 0.058 ps/nm^2/km (M. Vaa, OFC-01 paper WF5)



	LMF	NZ-DSF
A (um^2)	**70-80**	**50-55**
Dispersion slope	**0.05**	**0.1**

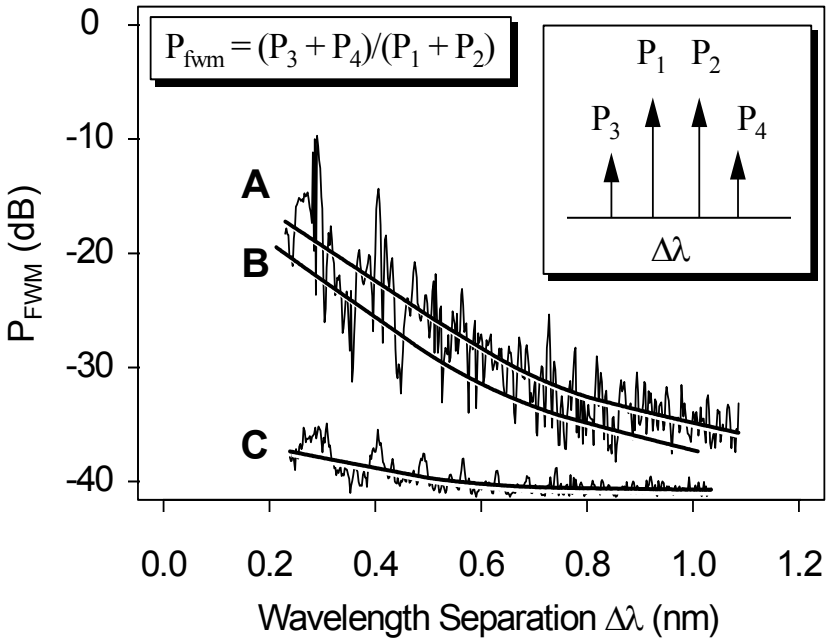
– Dispersion slope-matched map utilizing negative dispersion slope fiber can reduce slope to 0.005 ps/nm^2/km, realize > 1Tb/s submarine transmission (C. Davidson, OFC-00 PD-25)

4. Chirped Return-to-Zero (CRZ) transmission format

- Suppress nonlinear interaction by broadening the spectrum of launched signal.

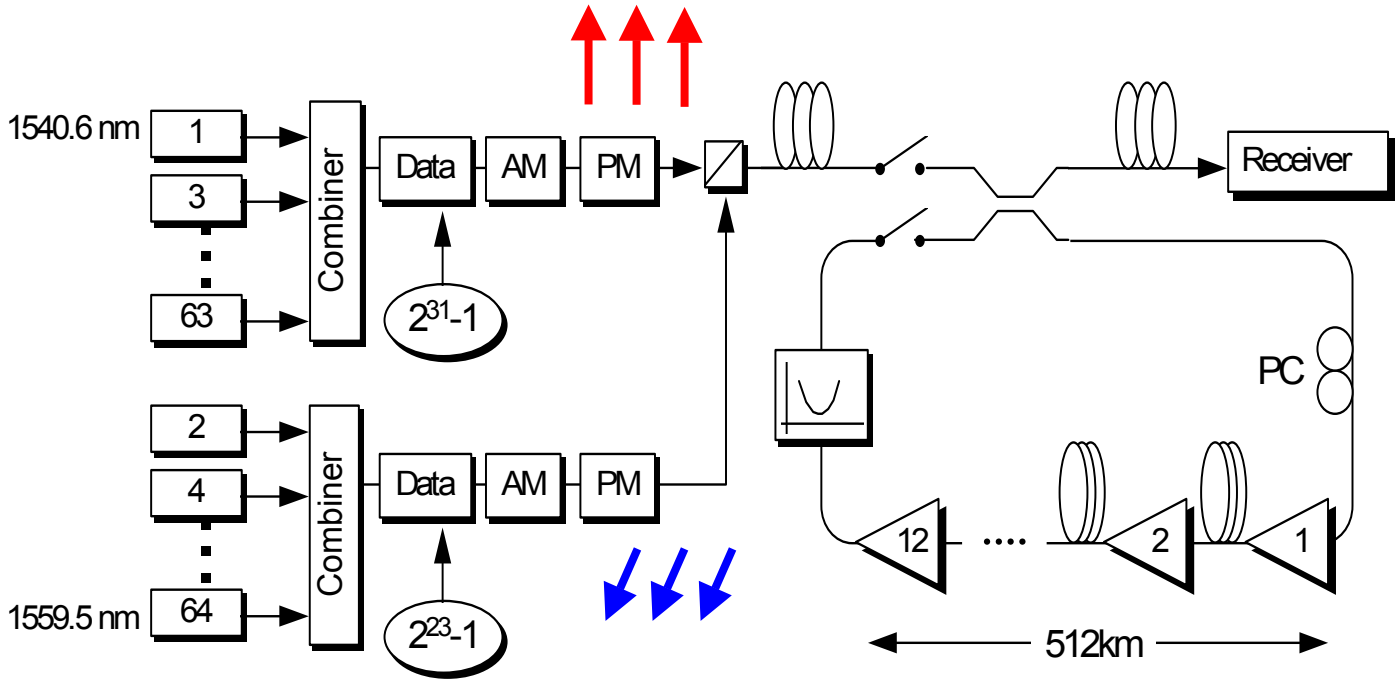
5. Orthogonal launch

- Orthogonal launch reduce XPM effect by half
- Orthogonal launch remove FWM effect



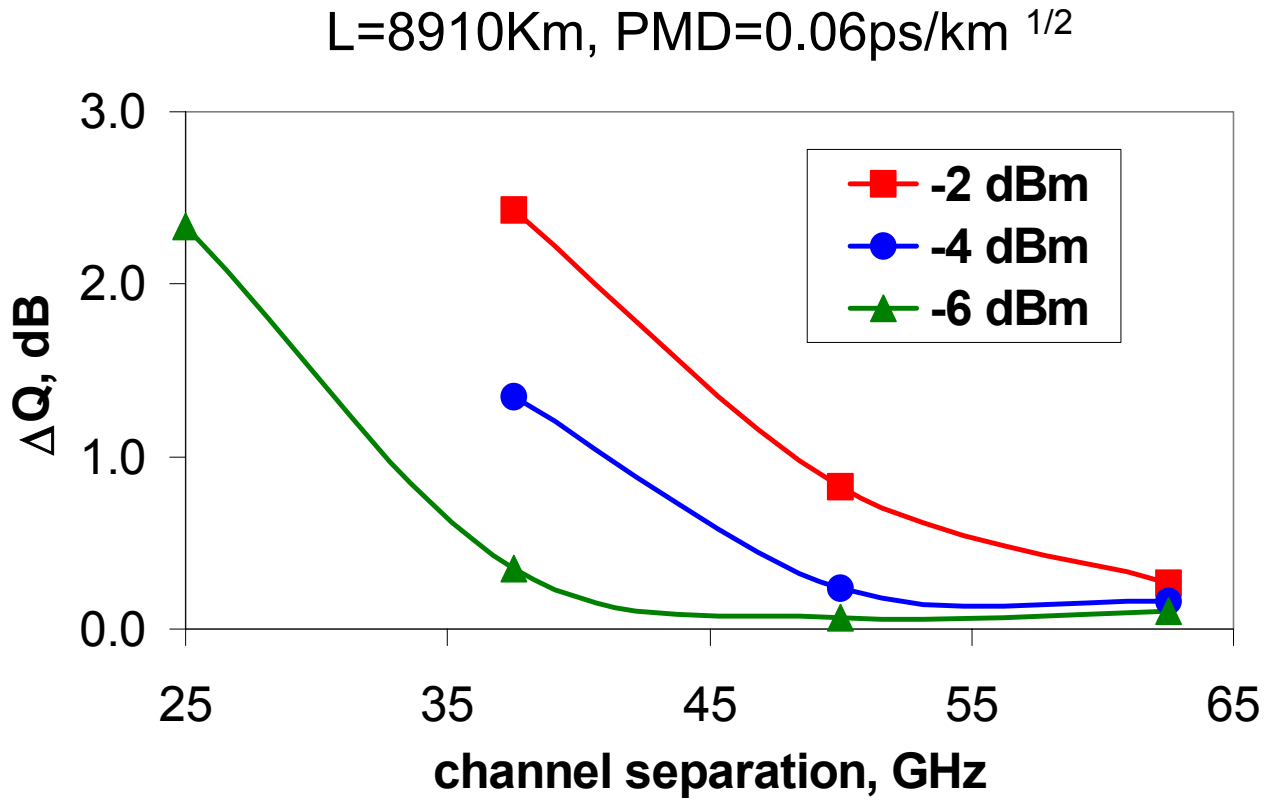
TWO-tone FWM vs Δλ in a 500 km amplifier chain for;
A) conventional WDM fiber, B) hybrid spans using large mode fiber, and C) orthogonal polarization launch.
N. Bergano, OFC98

Orthogonal launch technique



Neal Bergano, et. al. " 320 Gb/s WDM Transmission (64x5 Gb/s) over 7,200 km using Large Mode Fiber Spans and Chirped Return-to-Zero signal," OFC-98, paper PD-12

System Performance Improvement by orthogonal Launch

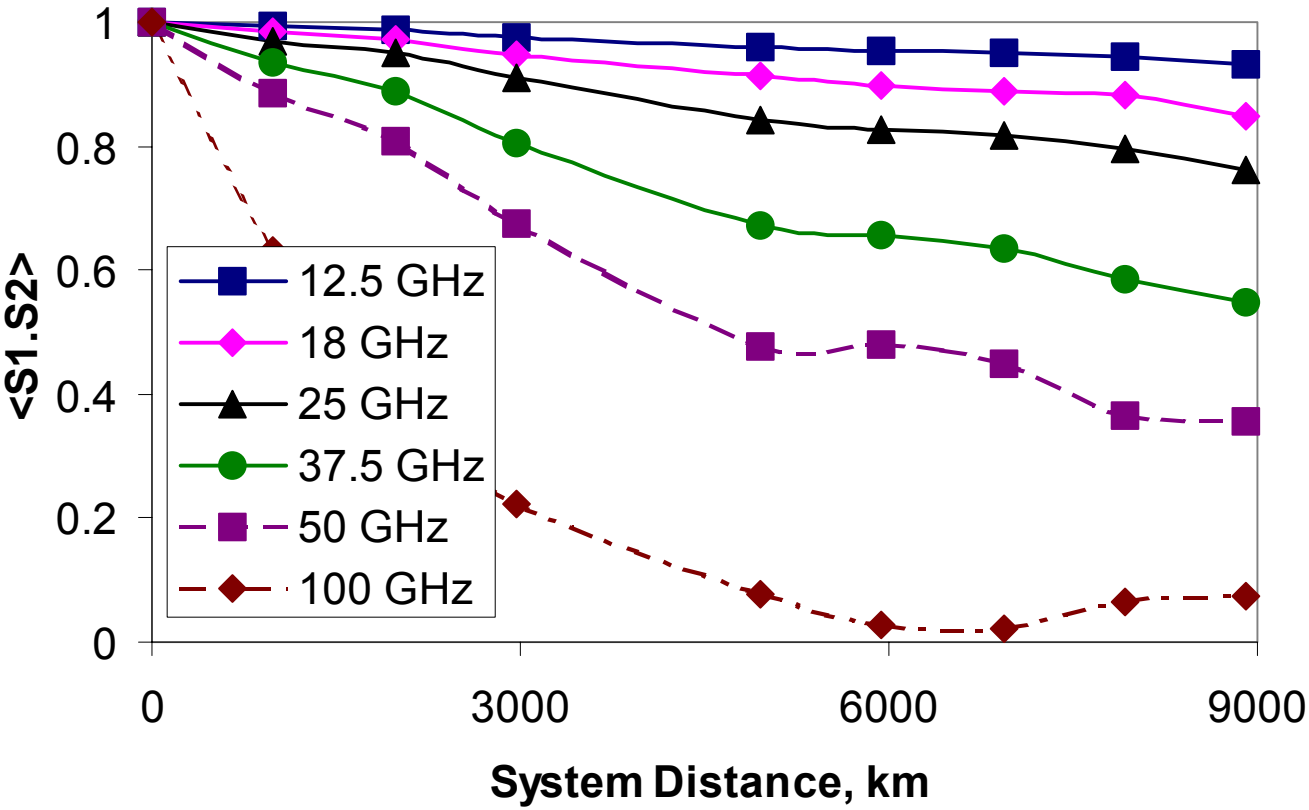


Dmitriy Kovsh, et. al., OFC-01 paper WT1

Bamdad Bakhshi, et. al., OFC-02 paper WP7

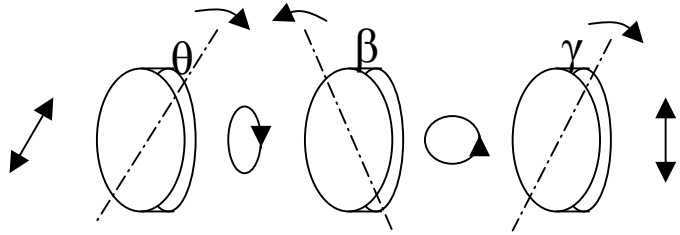
Orthogonally preservation between neighboring channels

PMD=0.06ps/km $^{1/2}$

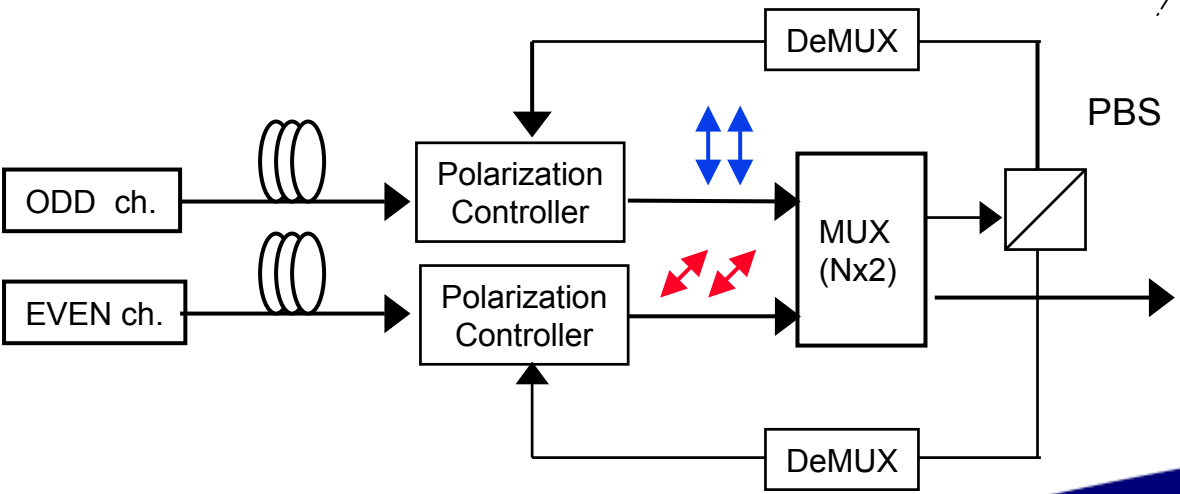


Polarization controller approach

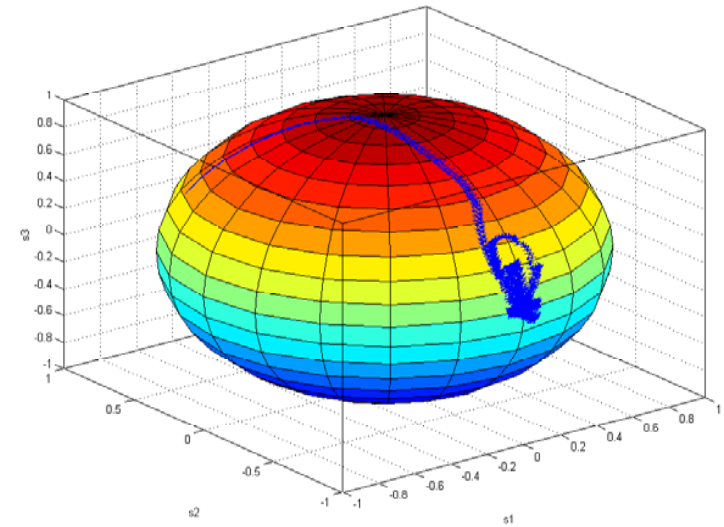
- LiNbO3 polarization controller can be modeled as a unitary Jones matrix relating the output and input Jones vectors



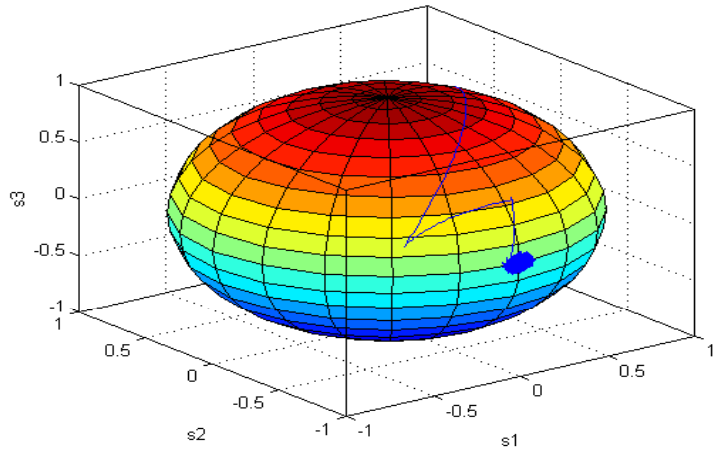
$$\vec{t} = \mathbf{U}(\theta, \beta, \gamma)\,\vec{s}$$



Loss control problem



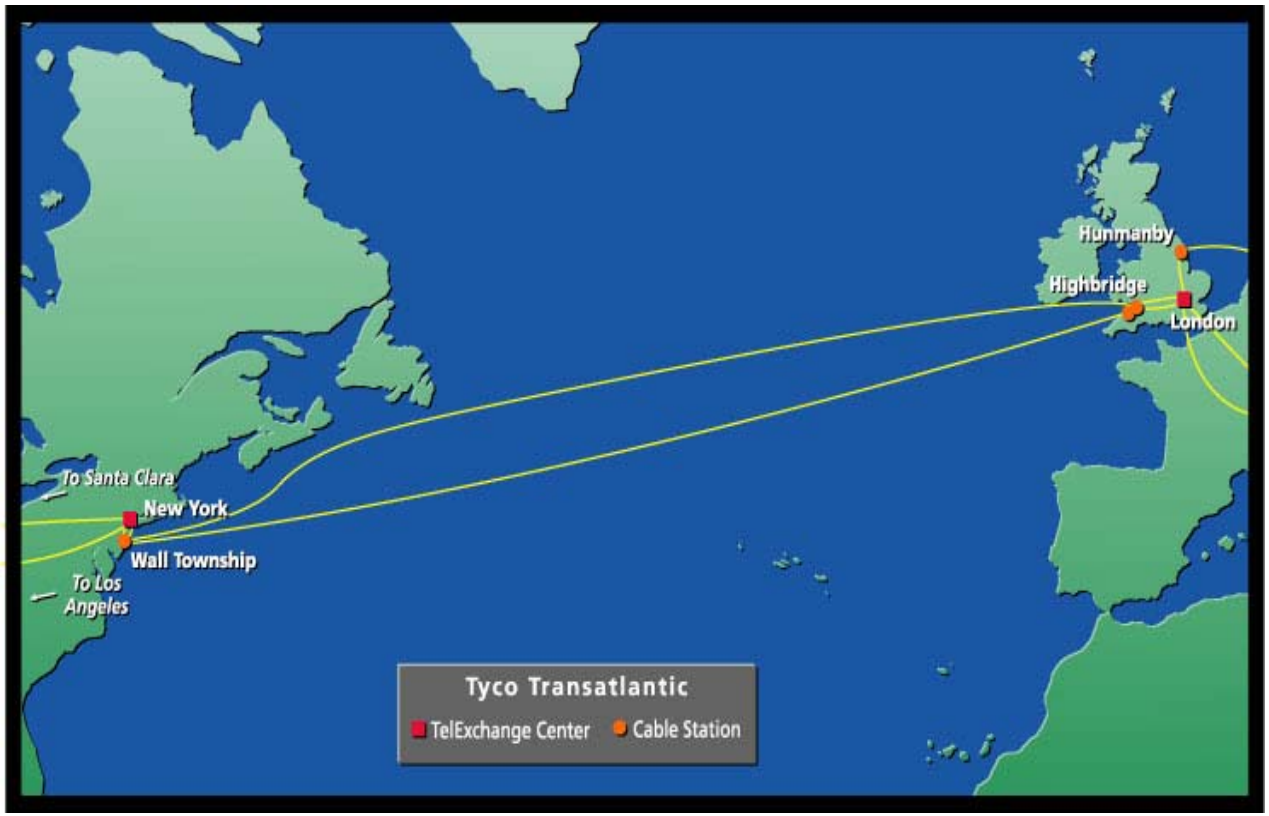
(a)



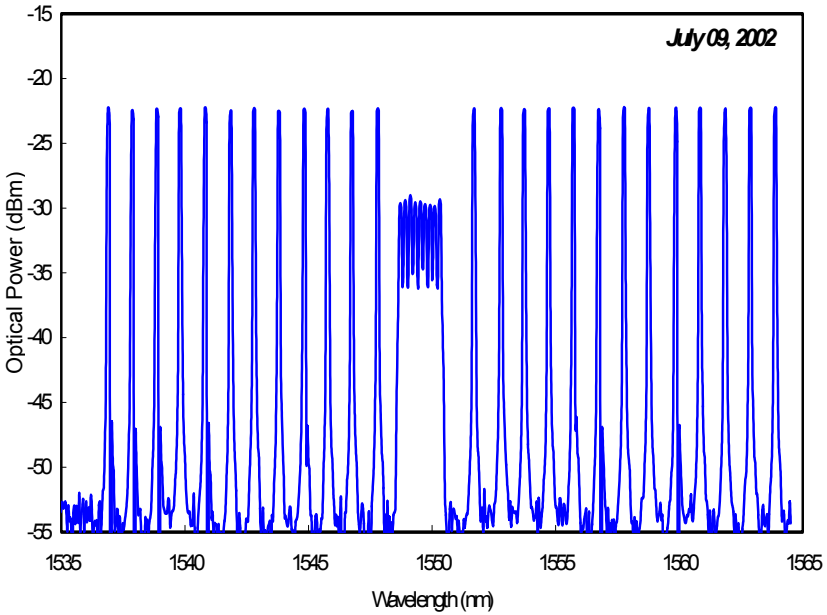
(b)

- Local gradient is searched by dithering the control parameters.
- There always exists an input polarization to the controller that is insensitive to dithering the control parameter.
  - W. Shieh and H. Kogelnik, IEEE Photonics Technology Letters, 2001
- Small change of input or output polarization requires large change of control variables
  - Fred Heismann. JLT 1994 (a)
- Tyco's Solution (b):
  - Intelligent dither algorithm changes the control variable by a large angle when there exists a "dead spot".

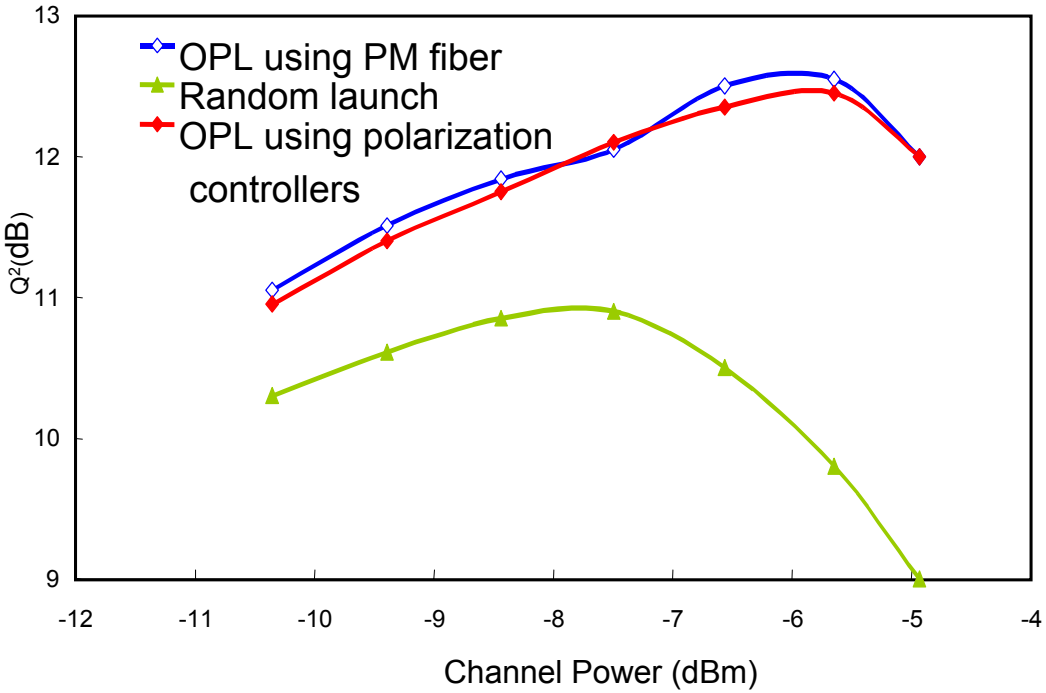
Trans-Atlantic 25 GHz channel spacing Experiment



TX spectrum



Performance of center channel at 1549.715 nm



- 9 data channels together with 25 depolarized CW loading tones.
- Data channel spacing is 25 GHz
- Data channel is RZ modulated with 13 dB spectral size band suppression

Conclusion

- DWDM system with narrow channel spacing (<0.3 nm) needs suppress nonlinear interchannel crosstalk.
- Orthogonal launch reduce XPM effect by one half and eliminates FWM effect,
- Practical orthogonal launch method exists.