40Gbit/s TRANSMISSION OVER 4000KM OF STANDARD FIBRE USING IN-LINE NONLINEAR OPTICAL LOOP MIRRORS

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Outline

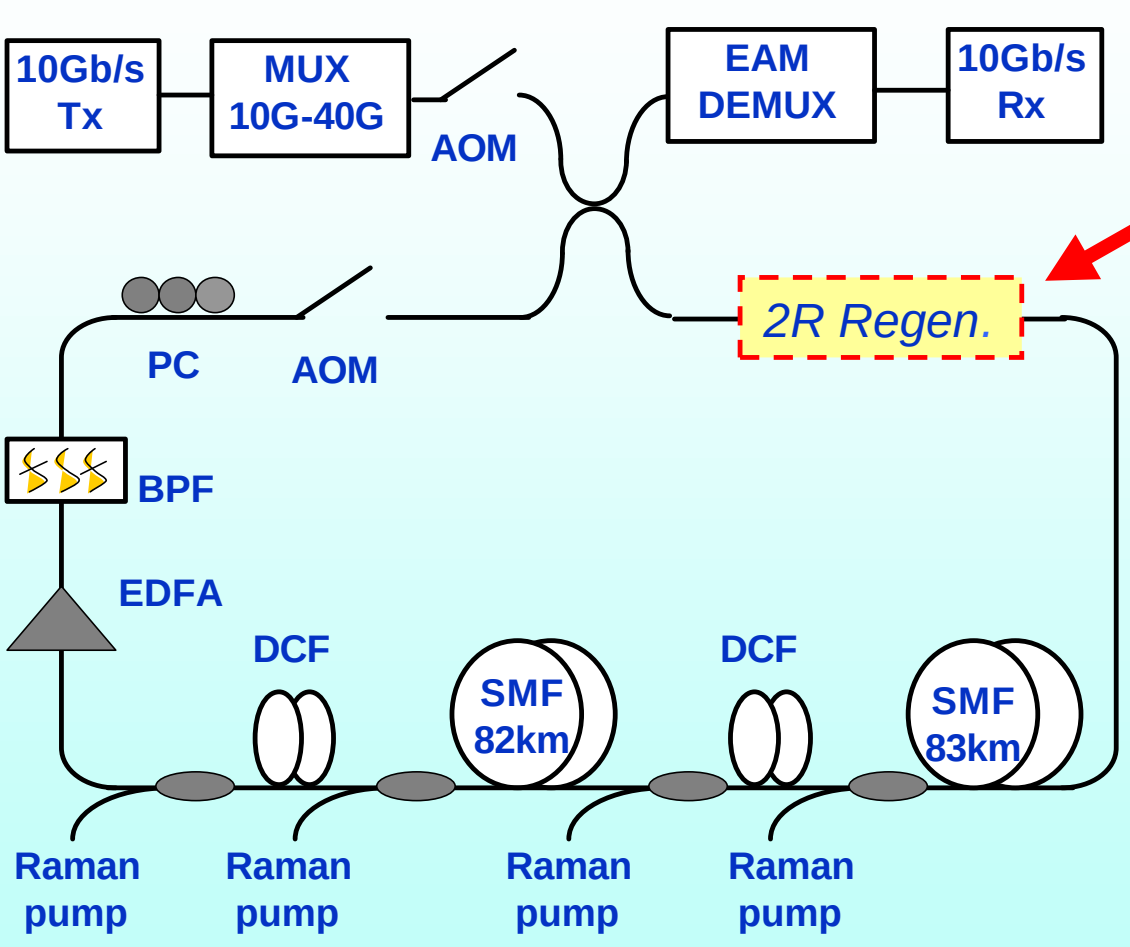
- **Introduction**
- **Experimental Setup**
  - Recirculating loop experiment, comparison of ‘generic’ and ‘NOLM-guided’ systems
  - Switching in the NOLM
- **Results**
  - Comparison of signal dynamics in the systems with/without 2R regeneration. Observation of autosoliton propagation regime.
  - Bit-error-rate at speeds of 10Gbit/s and 40Gbit/s
  - Evolution of temporal jitter. Jitter reduction in guided system.
- **Conclusion**

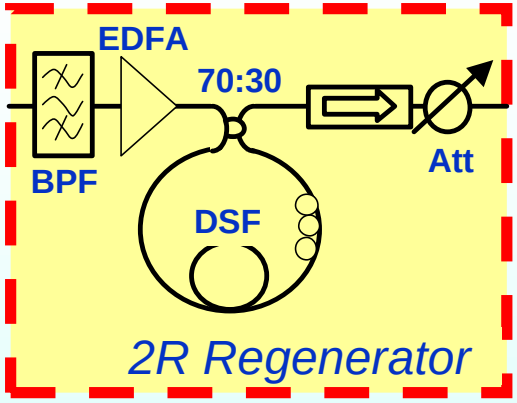
Introduction

- **Switching in nonlinear optical loop mirror (NOLM) - similar to saturable absorption.**
- **NOLM switch can be used for 2R regeneration[1]**
- **Existence of autosolitons predicted in dispersion managed systems guided by nonlinear loop mirrors [2]**
- **NOLMs used in experiments for pulse shaping in transmitter [3], signal filtering at receiver [4], but not for in-line 2R**

[1] N. J. Smith and N. J. Doran, J. Opt. Soc. Am. B, 12, 1117-1125 (1995).
[2] S. Boscolo, J.H.B. Nijhof, and S.K. Turitsyn, *Opt. Lett.,* Vol. 25, p.1240, (2000).
[3] Yikai Su, *et al*, Electron. Lett., vol. 38(2002), pp.573-574.
[4] I. Y. Khrushchev, *et al*, *Electron. Lett.* , vol. 35(1999), pp. 1183-1185.

Recirculating loop experiment





Dispersion map strength

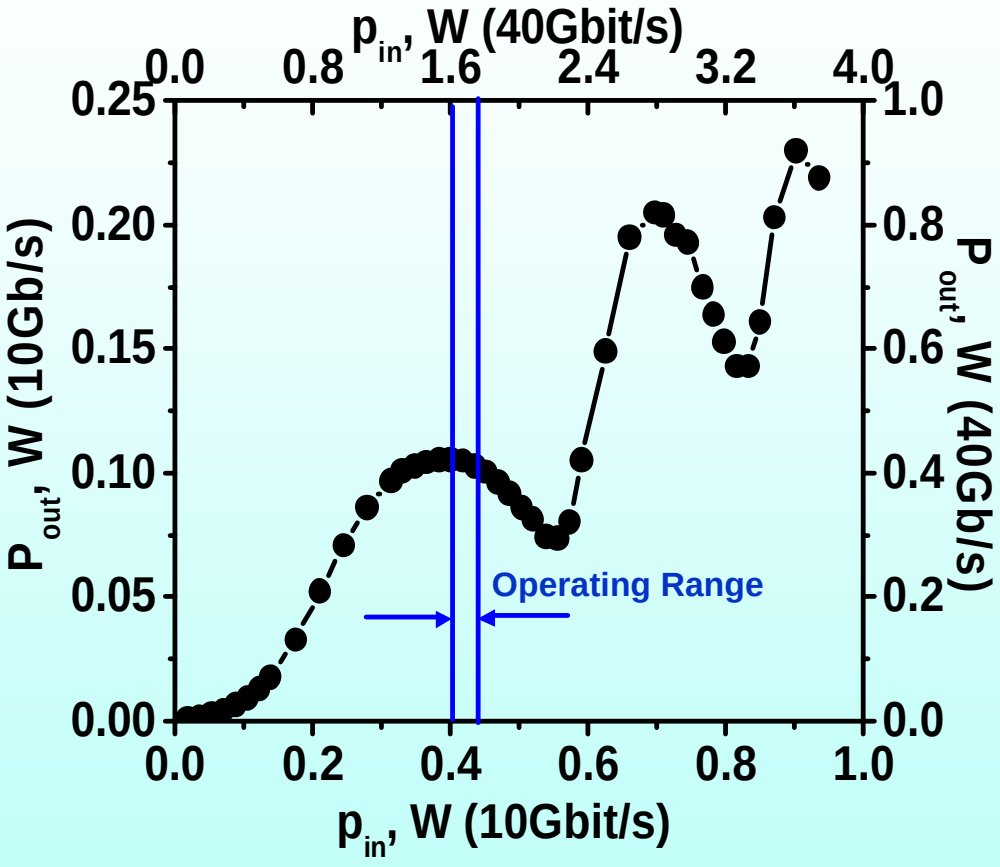
S ~ 280

Average dispersion in fibre span +0.003ps/(nm.km)

SMF = standard telecom-s fibre(Corning SMF-28)

DCF = dispersion compensating fibre

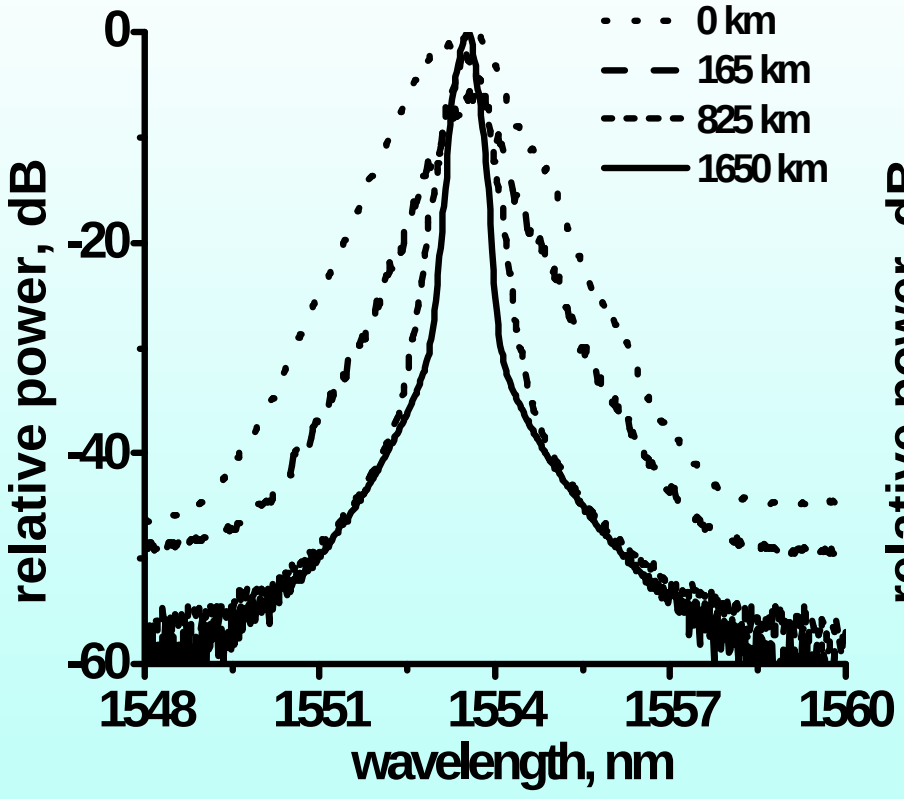
Switching in the NOLM



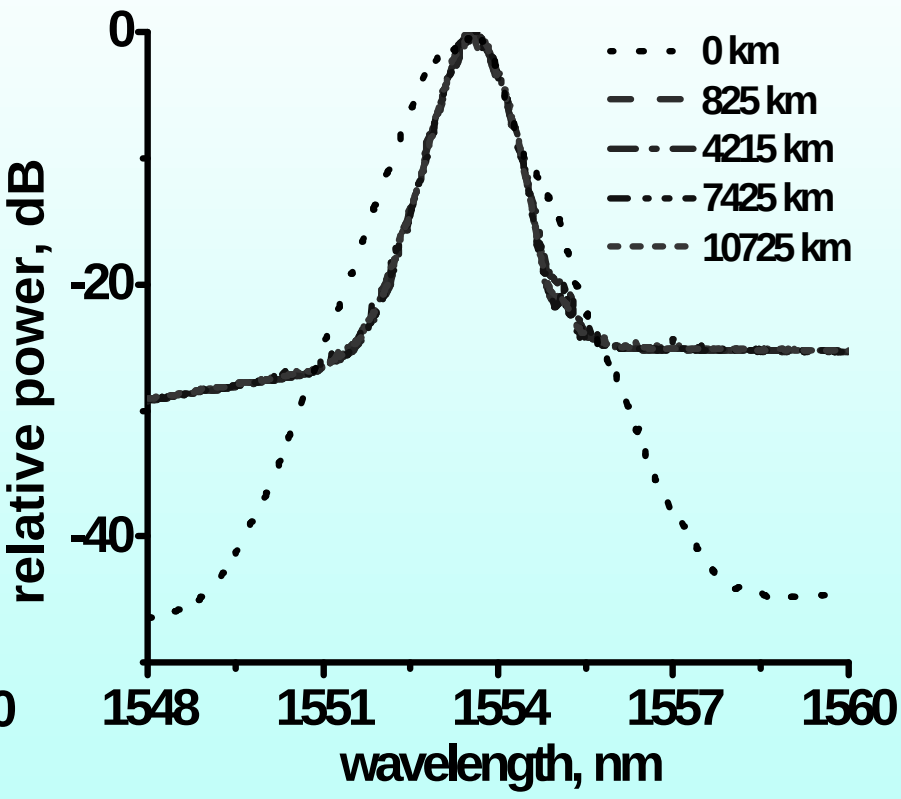
- Measured back to back
- Asymmetry introduced by 70:30 coupler
- Pulses in the NOLM similar to solitons
- Operation point close to the first transmission peak ® suppression of amplitude fluctuations

Spectral evolution at 40Gbit/s.

Generic system (no 2R)

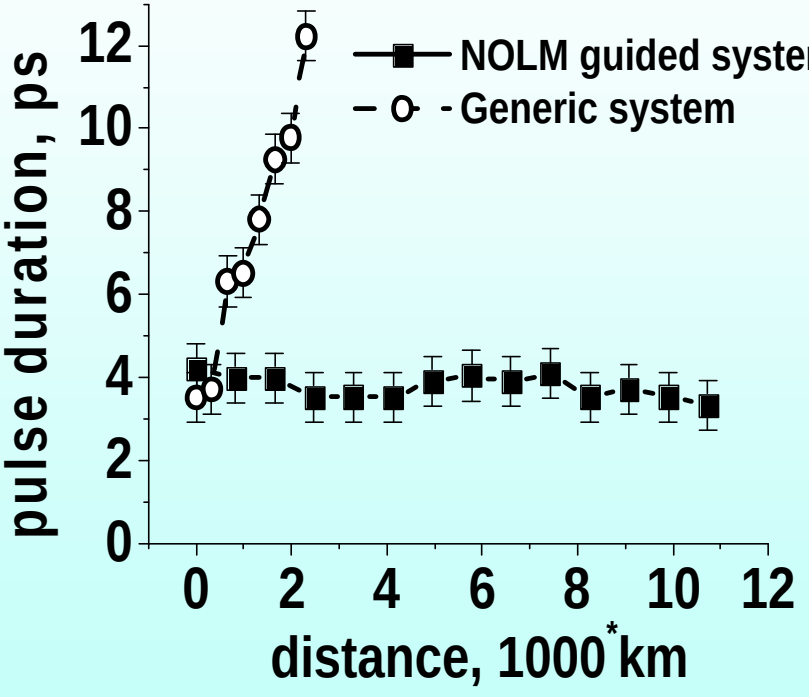


NOLM - guided system

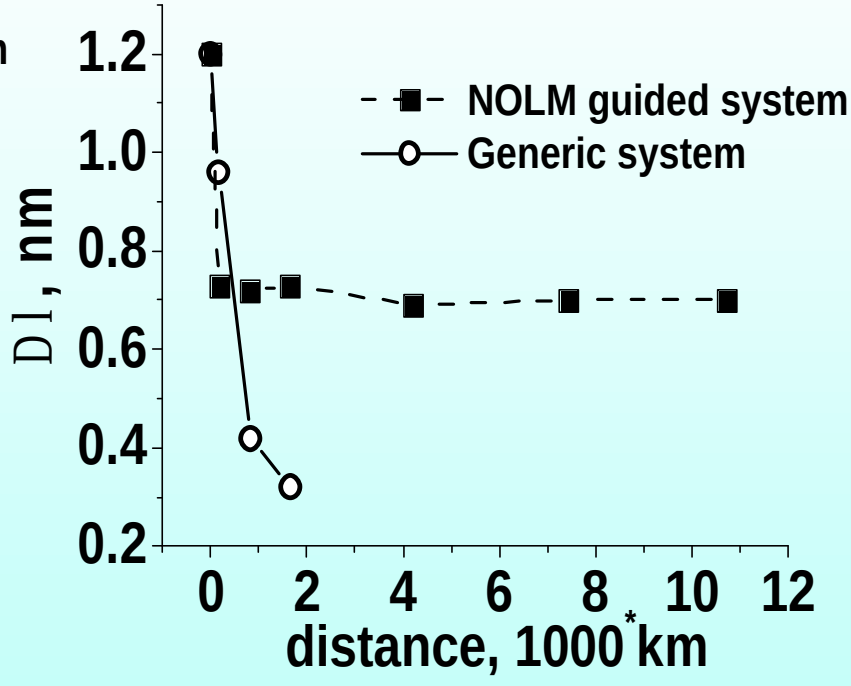


Temporal and spectral evolution at 40Gbit/s.

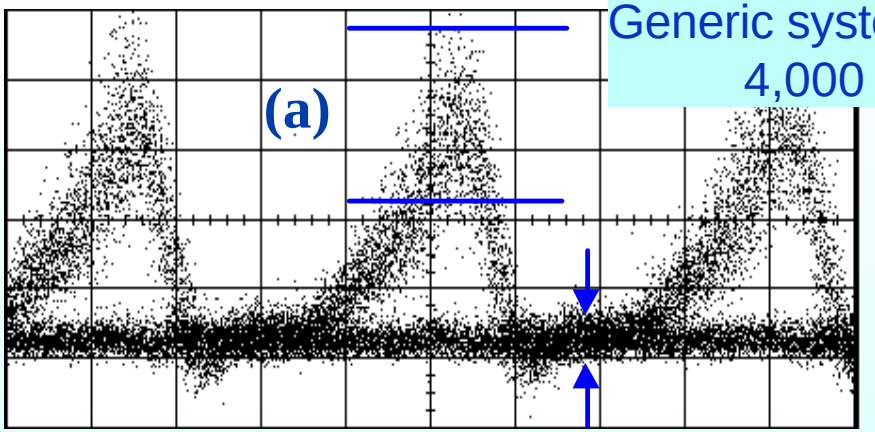
Pulse duration



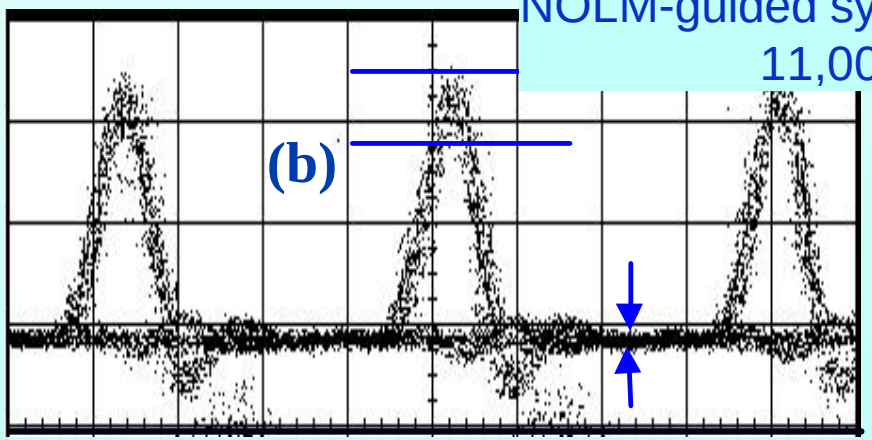
Spectral bandwidth



10Gbit/s transmission. Eye diagrams.



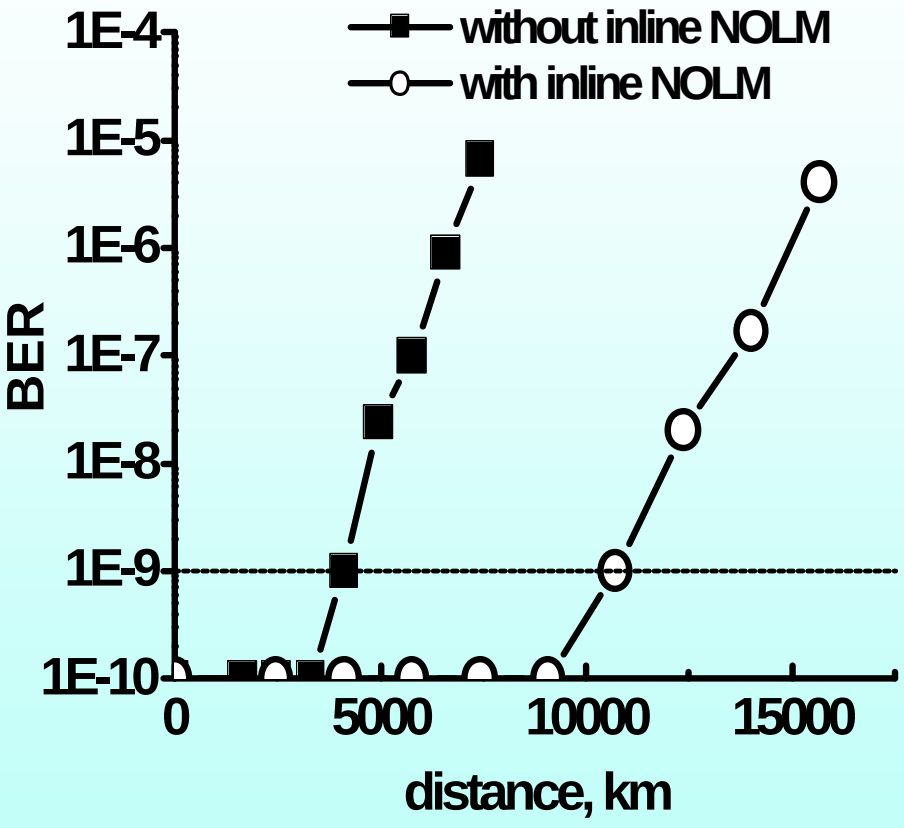
Generic system
4,000 km



NOLM-guided system
11,000 km

- **Significant suppression of 'zeros' noise**
- **Significant reduction of amplitude fluctuations, 'ones' noise**
- **Temporal jitter is reduced due to suppression of pulse-to-pulse interactions**

10Gbit/s transmission. BER.



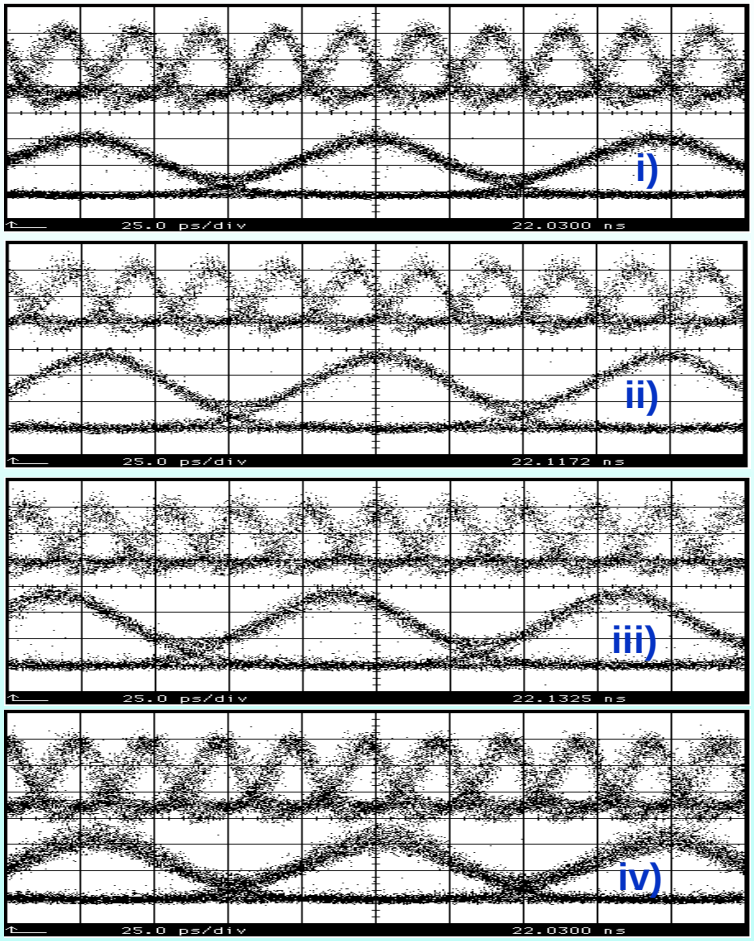
- Generic system. Error free transmission distance, 4,000 km.
- NOLM-guided system. Error-free transmission, 11,000 km.

Measured transmission distance is *physically-limited*, i.e. no forward-error correction (FEC) was used.

NOLM guided, 40Gbit/s transmission. Eye diagrams.

40Gbit/s

Demux 10Gbit/s



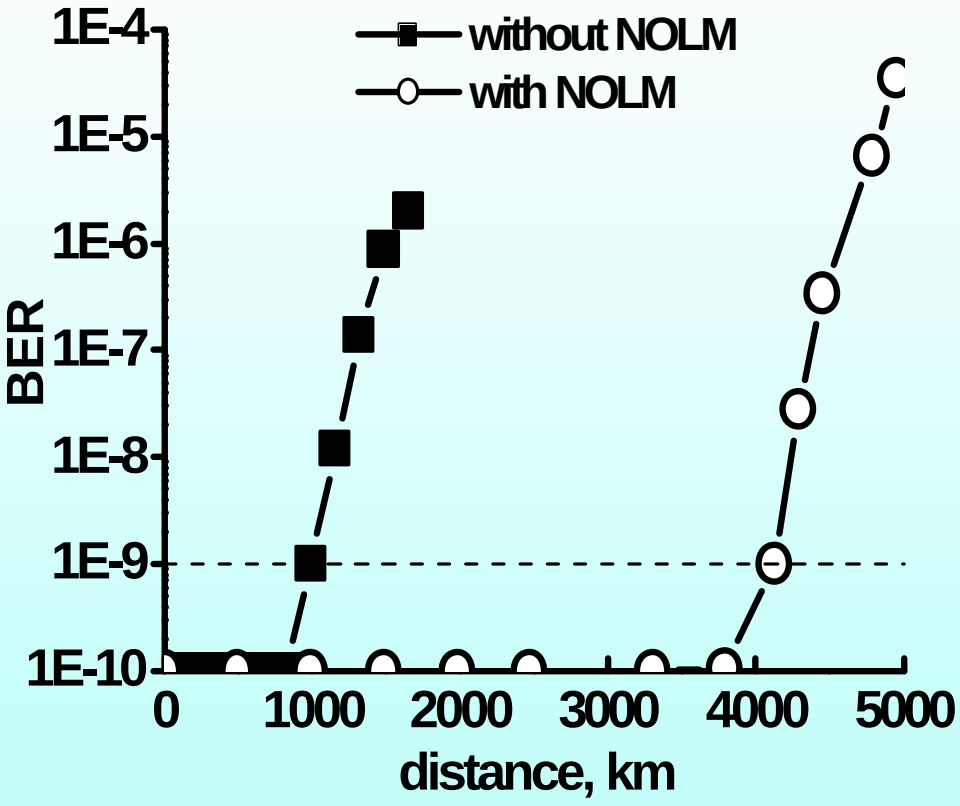
i) 2500km, no signal degradation

ii) 4000km,some degradation

iii) 6000km, Q value ~8 estimated from eye

iv) 7500km, Q value ~6 estimated from eye

NOLM guided, 40Gbit/s transmission. BER.

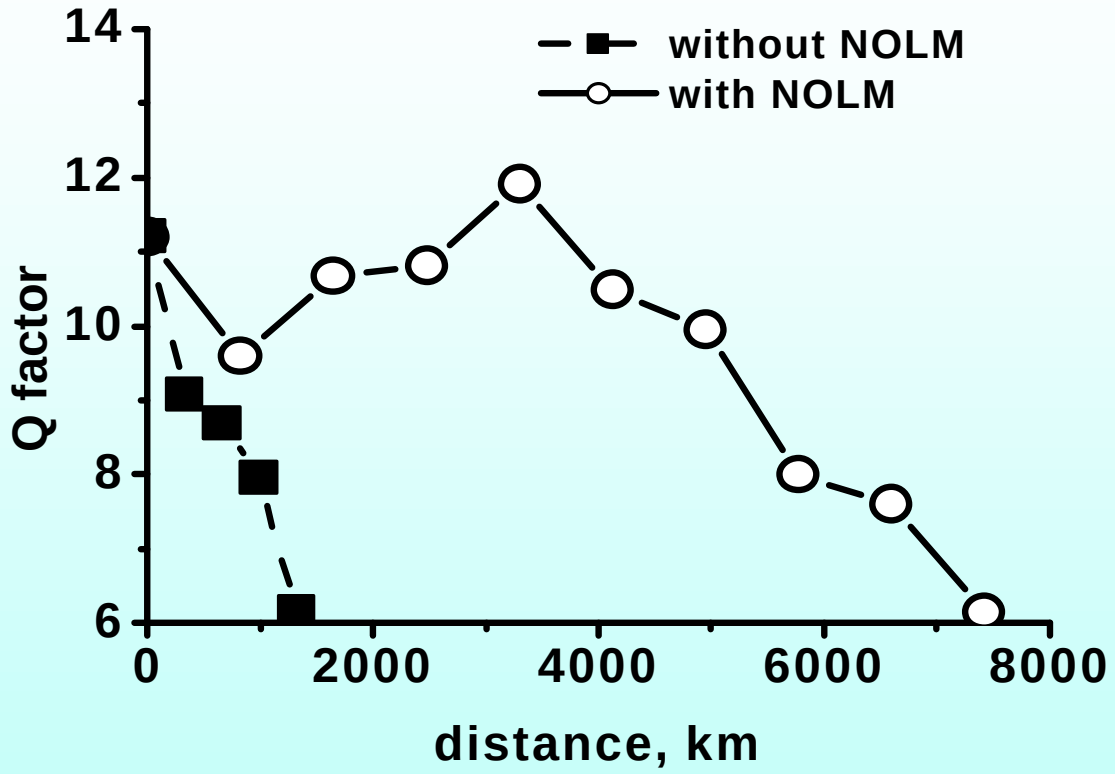


- Generic system. Error free transmission distance, 1,000 km.
- NOLM-guided system. Error-free transmission, 4,000 km*.

* latest result: 6,000 km in NOLM-guided link !

Total fibre length=7200 km including DCF

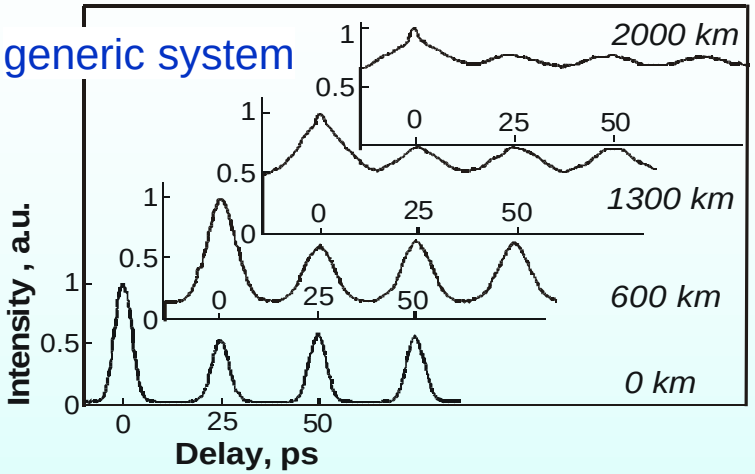
NOLM- guided, 40Gbit/s transmission. Q-factor.



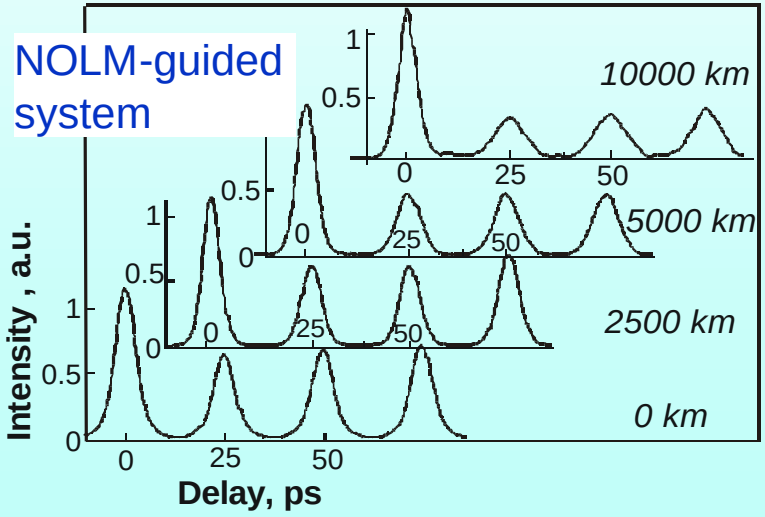
Q-factor estimated from oscilloscope traces

Temporal jitter evolution at 40Gbit/s.

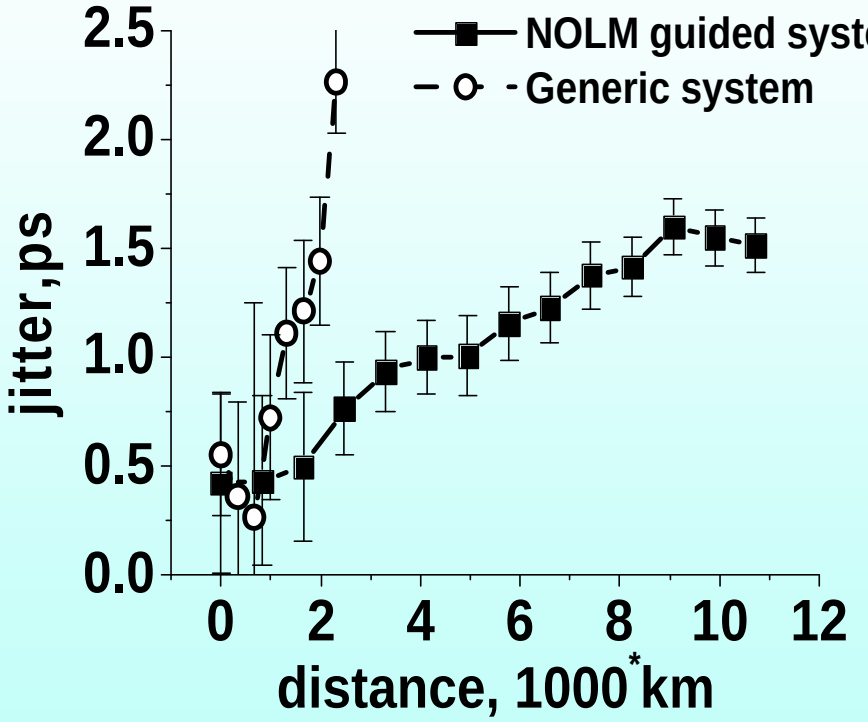
generic system



NOLM-guided system



Jitter estimated from autocorrelation measurements.



Conclusion.

- Autosoliton propagation in a dispersion managed transmission system controlled by in-line NOLMs has been experimentally demonstrated for the first time.
- Physically-limited, error-free propagation distance of 11,000km at the speed of 10Gbit/s has been achieved in the NOLM-guided system compared to 4,300km in the generic system.
- Transmission distance increase from 1000km to 6,000km has been achieved at the speed of 40Gbit/s in standard fibre.
- Increase rate of temporal jitter is reduced by a factor of 5 in the NOLM-guided system due to suppression of pulse-to-pulse interactions.