

Optical Communication Systems: Breaking Capacity Limits

Mutual Information

- Mutual Information (MI) is the largest transmission rate for a particular channel input
- If we transmit at or below MI, the error probability can be made arbitrarily small
- MI inherently assumes ideal error correction
- For channel input X , channel output Y , channel $q_{Y|X}$, MI is estimated as

$$MI \triangleq \frac{1}{N} \sum_{i=1}^N \log_2 \frac{q_{Y|X}(y_i | x_i)}{q_Y(y_i)}$$

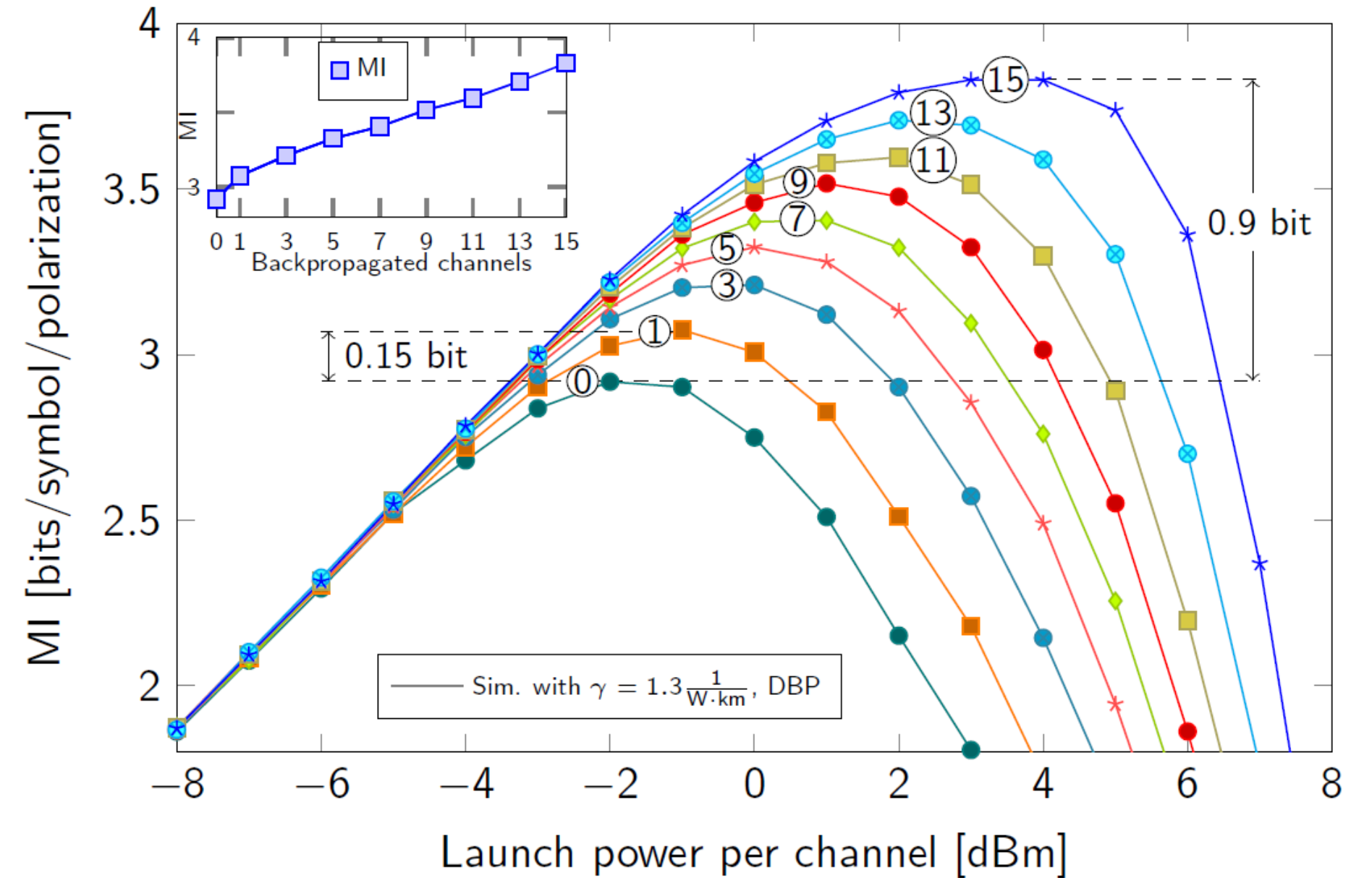
Application: Digital Backpropagation

- Nonlinear fiber effects limit data rates in optics
- DBP undoes these perturbations digitally
- Neighboring WDM channels often unknown at RX
- Superchannel: Densely spaced WDM channels that are jointly transmitted, routed and processed
- All information about co-propagating channels available at receiver

How much do we gain by (partly) back-propagating a superchannel?

Results

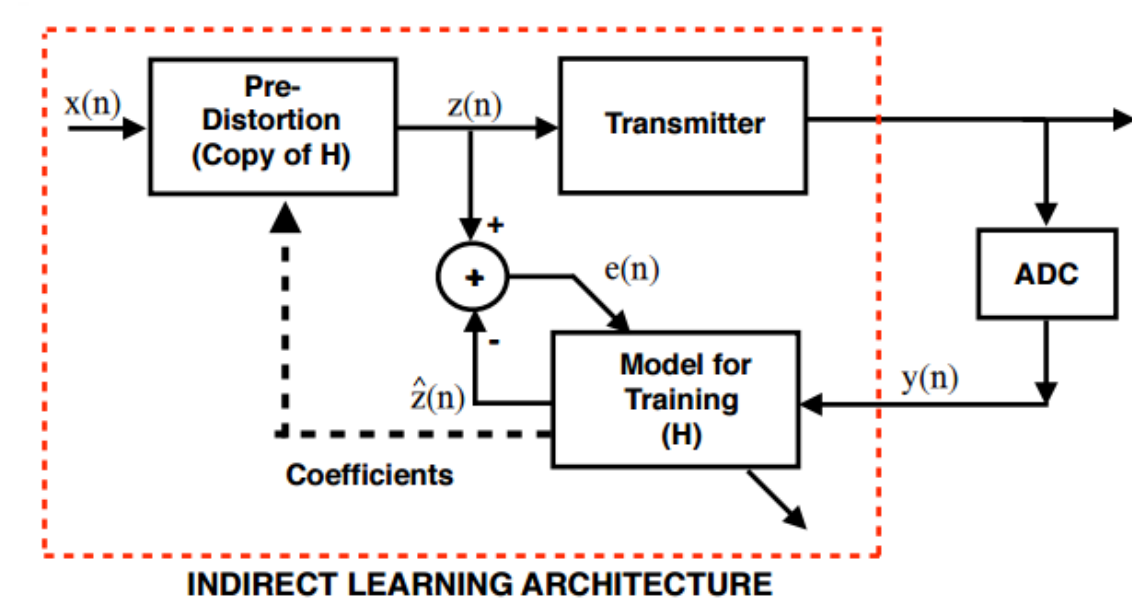
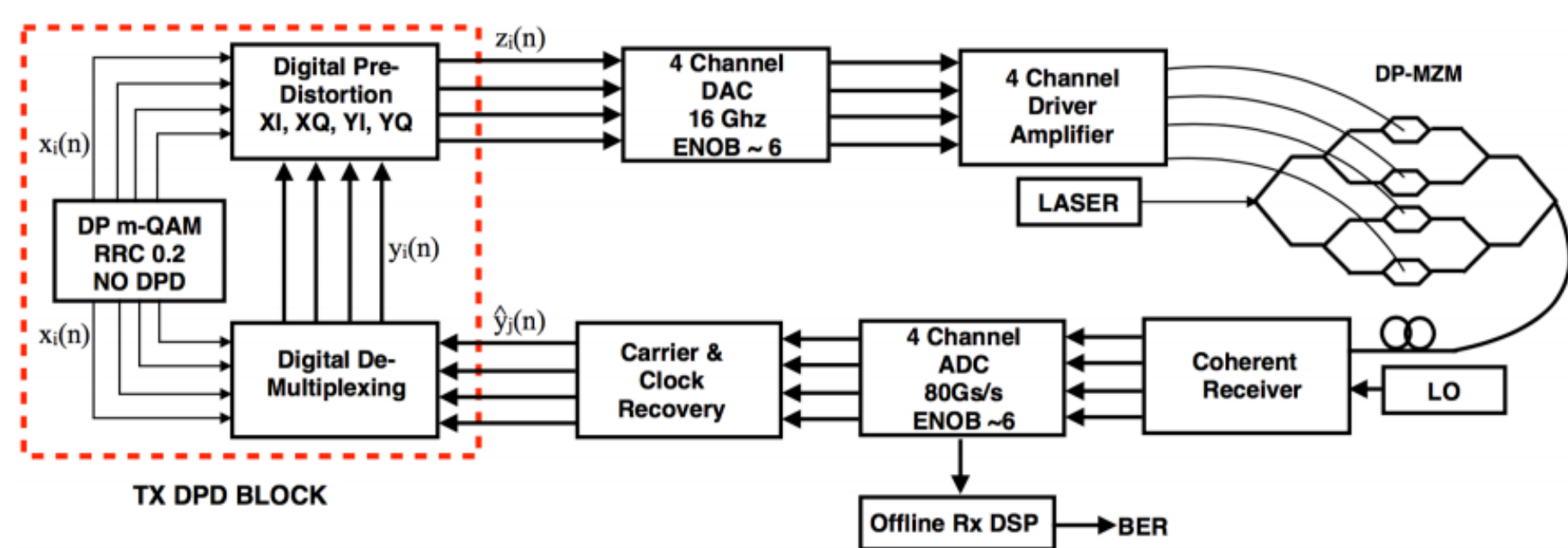
Sim. Results: Back-propagation of k Channels



- DBP of one channel vs. no DBP: 0.15 bit/symbol gain (11.2 Gbit/s increase for center channel)
- Full-field DBP (15 channels) vs. no DBP: 0.9 bit/symbol gain (50 Gbit/s increase per channel)
- But: Huge complexity of full DBP

Adaptive Pre-Compensation

- Continuous increase of world-wide data traffic
- Optical communication systems operated at their physical limits
- Severe degradations due to transmitter impairments: bandwidth-limitations, skew, non-linear effects
- Mitigation by Adaptive Pre-Distortion:



Indirect Learning Architecture with Memory Polynomial Based Model:

$$\hat{z}_i(n) = \sum_{p=1}^P \sum_{m=-(M_p-1)/2}^{(M_p+1)/2} h_{i,m,p} y_i^p(n-m)$$

Results

- 400Gbit/s/channel transmission over Telecom Itala Metro link
- Error free transmission of 30x400G 64QAM and 30x400G 128QAM over 80km of legacy fiber network

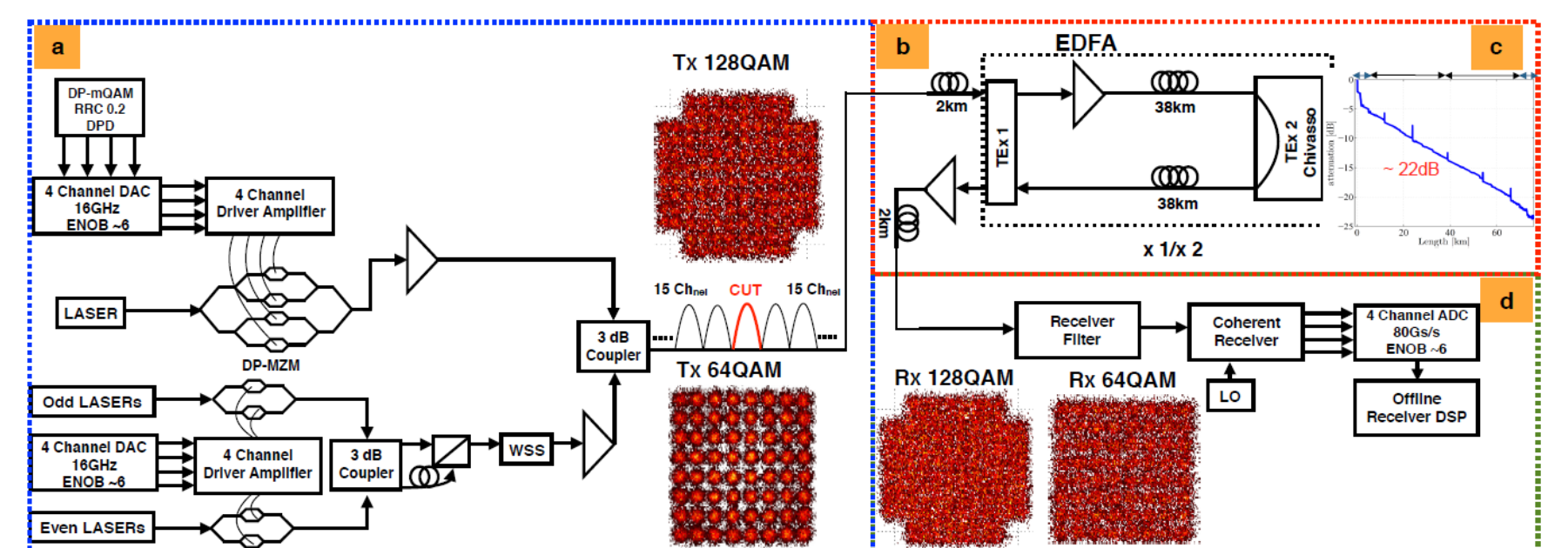


Fig. 1: Experimental Link Setup (a) Transmitter (Torino) with test and neighboring channel setup (b) Link (connecting Torino, TE1 and Chivasso in a loop back configuration at TE2); (c) OTDR trace of 80km link (d) Receiver at Torino

Modulation Format	Baud Rate (GBaud)	Net Bit Rate (Gb/s)	FEC Overhead	FEC Threshold	Spacing Used (GHz)	Sp.Efficiency (bits/s/Hz)
DP-64QAM	45.25	400	25%	4.2E-02	56.25	7.1
DP-128QAM	42.0	400	35%	6.0E-02	56.25	7.1

