Rate Optimized Probabilistic Shaping-Based Transmission Over Field Deployed Coupled-Core 4-Core-Fiber

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A. Nespola[1], M. A. Amirabadi[2,3], R. Ryf[4], M. Mazur[4], N. K. Fontaine[4], L. Dallachiesa[4], T. Hayashi[5], M. H. Kahaei[3], S. A. Nezamalhosseini[3], A. Marotta[6], A. Mecozzi[6], C. Antonelli[6], and A. Carena [2]

1. LINKS Foundation, Torino, Italy, 2. Politecnico di Torino, Torino, Italy, 3. Iran University of Science and Technology, Tehran, Iran, 4. Nokia Bell Labs, Murray Hill, NJ, USA, 5. Sumitomo Electric Industries, Ltd., Yokohama, Japan, 6. Università Degli Studi Dell'Aquila, L'Aquila, Italy

Multi-core fiber (MCF) transmission is a promising solution to support ever-increasing future traffic demands. Compared with uncoupled-core MCFs [1], the induced strong coupling in coupled-core (CC)-MCFs reduces the nonlinearity impact [2]. Transmission in these fibers leverages both spatial and wavelength division multiplexing and it has been experimentally tested mainly considering uniform quadrature amplitude modulation (QAM) formats [3]. Spectral efficiency can be further optimized by employing probabilistic shaping (PS) but the joint use of CC-MCF and PS has been rarely investigated [4]. In this paper, we present a transmission of PS signals through an infrastructure based on a CC-four core fiber (CC-4CF) deployed in the city of L'Aquila, Italy [5]. We ran experiments comparing the performance of standard polarization multiplexed 16QAM and PS-32QAM signals at a symbol rate of 30 GBaud: 800 Gbps net rate considering the spatial super-channel over four cores. We used the generalized mutual information (GMI) as performance metric and averaged over the 8 polarizations concidering the central channel. A realistic threshold (GMI_{th}) of 3.6 bits/symbol (per spatial mode and polarization) has been set as a target: it is a typical value that guarantees post-FEC error-free transmission for most realistic SD-FEC.

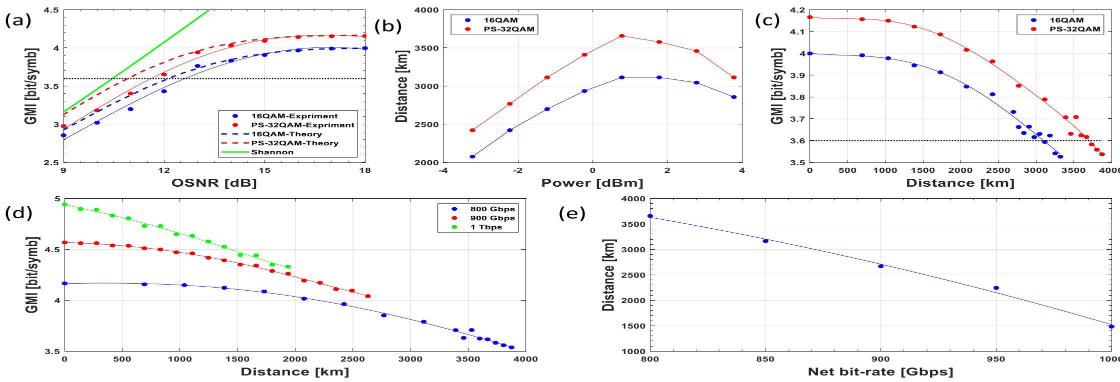

Fig. 1 a) GMI versus OSNR in B2B condition, b) Maximum achievable distance at GMI_{th} as a function of launched power, c) GMI evolution versus distance at the optimum power, d) GMI versus distance at the optimum power for different net rates, and e) Maximum achievable versus distance as a function of net rate.

We started with the back-to-back (B2B) characterization: Fig. 1a shows GMI versus optical signal to noise ratio (OSNR) for 16QAM and PS-32QAM. Markers report measured values (fitted with solid lines) compared with theory (dashed lines). PS-32QAM has 0.64 dB penalty at GMI threshold (black dotted line), similar to 16QAM (0.54 dB). Our transceiver setup confirms the linear advantage of PS-32QAM compared to 16QAM: it shows a gain of 1.16 dB. Then we moved to the WDM transmission over the CC-4CF considering 21 channels spaced 50 GHz: averaging 6 measurements, we determined the maximum achievable distance at GMI_{th} for the central channel as a function of launched power level. Fig. 1b shows that 16QAM reaches 3114 km while PS-32QAM reaches 3668 km. PS outperforms the uniform QAM (+17% in reach) but partially loses its original advantage (+31% in B2B) due to its known larger nonlinear penalty. Fig. 1c shows that PS maintains its advantage over long distances, up to 4000 km. In Fig. 1d, we compare experimental results for PS-32QAM using three different shaping factors, corresponding to spatial super-channel net rates of 800 Gbps, 900 Gbps, and 1 Tbps, respectively. In Fig. 1e, we report the maximum reach for different net rates. Net rate can be optimized with respect to distance: when the required reach is about 3600 km, a channel can deliver 800 Gbps. While for shorter distances, around 1500 km, we can increase the speed to 1 Tbps. Moreover, PS allows for fine rate tunability, beyond the 50 Gbps granularity shown in Fig. 1e.

This work was supported by the Italian Government through projects PRIN 2017 FIRST and Project INCIPICT.

References

[1] R. S. Luis, et al. "372 Tb/s Unrepeatered 213 km Transmission Over a 125 μm Cladding Diameter, 4-Core MCF", *In OFC*, 2022.
[2] C. Antonelli, et al. "Modeling of nonlinear propagation in Space-Division Multiplexed fiber-optic ...", *JLT*, 34(1), 36-54, 2016
[3] R. Ryf, et al. "Transmission over randomly-coupled 4-core fiber in field-deployed multi-core fiber cable", *In ECOC*, 2020.
[4] M. Arikawa, et al. "Long-Haul Transmission over Coupled MCF with Coupled Core EDFA", *In OECC-PSC*, 2022.
[5] N. Sambo, et al. "Field trial of SDN-controlled probabilistic constellation shaping supporting multiple rates over ...", *In ECOC*, 2022.