Supplementary Information: Coherent optical communications using coherence-cloned Kerr soliton microcombs

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1 Influence of fiber nonlinearity on microcomb re-generation and data interconnect.

As mentioned in the main text, the pump laser $C_{\mathrm{Tx}}(0)$ and pilot tone $C_{\mathrm{Tx}}(17)$ of the transmitter comb propagate through the 50 km fiber link together with the high speed data signals . A matter of concern is that the data signals may impose linewidth broadening to them via cross-phase modulation (XPM) and may degrade their spectral purity as the conveyed pump laser and reference pilot [1]. Here we conduct numerical simulation to investigate how $C_{\mathrm{Tx}}(0)$ and $C_{\mathrm{Tx}}(17)$ are impacted by fiber nonlinearity. The simulation contains 20×21 GBaud single-polarization 16QAM signals with a spacing of 100 GHz. The 0th and 17th frequency bins are not modulated to mimic the $C_{\mathrm{Tx}}(0)$ and $C_{\mathrm{Tx}}(17)$. The data on each channel are uncorrelated among the other channels. The power of each data channel is set to 0 dBm, in consistency with the experimental situation. The fiber length is 50 km in our experiment without intermediate amplification.

Fig. S1 shows the simulation results. It is seen that when the fiber chromatic dispersion is turned off in the simulation, XPM induces sizable temporal phase drifts on the pump laser and pilot tone. In our simulation the temporal phase drifts are extracted by beating them with a

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zero-linewidth laser tone thus converting their phase fluctuations into amplitude fluctuations. To the contrary, when the fiber chromatic dispersion is turned on, XPM induced phase fluctuations become much smaller. As interpreted in the main text, chromatic dispersion of the fiber induces spatiotemporal walk-off among signals at different wavelengths (i.e., different data channels) along the transmission link, therefore, XPM imposed to the pump laser $C_{\mathrm{Tx}}(0)$ and pilot tone $C_{\mathrm{Tx}}(17)$ from different data channels are smoothed out as a quasi-constant phase envelop without high frequency component, which would not impact their efficacy as pump laser and pilot tone.

To confirm the above numerical analysis, we conduct a separate experiment where the 20 data channels are transmitted to the receiver within a different fiber from the pump laser $C_{\mathrm{Tx}}(0)$ and pilot tone $C_{\mathrm{Tx}}(17)$, so that to totally eliminate the XPM interactions between data channels and the pump/pilot tones. As shown in Fig. S1c, data receiving SNR and BER are identical regardless of whether one fiber or two fibers are adopted, confirming that XPM causes no prominent influence in our system.

2 Optical phase lock loop for two-point locking of the transmitter and receiver microcombs.

The schematic of the optical phase lock loop (OPLL) for locking $C_{\mathrm{Tx}}(17)$ and $C_{\mathrm{Rx}}(17)$ is presented in Fig.S2. The ∼941.1 MHz beat note between the $C_{\mathrm{Tx}}(17)$ and $C_{\mathrm{Rx}}(17)$ is produced using a fast photodetector, which is then down mixed within a double-balanced mixer to zero with a 941.1 MHz local oscillator signal from a signal synthesizer. The down mixed signal is low-pass filtered and used as the error signal in a proportional–integral–derivative controller (PID, Newport LB1005), which generates the control signal to actuate the amplitude modulation of the auxiliary laser for generating and tuning C_{Rx}, with a feedback loop bandwidth of 100 kHz. The actuation response speed of the repetition rate of C_{Rx} is considered faster than the loop bandwidth, as instantaneous change of the pump laser detuning can be imposed by the change of intra-cavity power of the auxiliary laser through the effect of XPM [2]. The residual phase noises from the OPLL and the signal synthesizer are considered responsible for the imperfect phase coherence between the carrier and LO (see Fig. 1 and Fig. 3 of the main text) after two-point locking.

References

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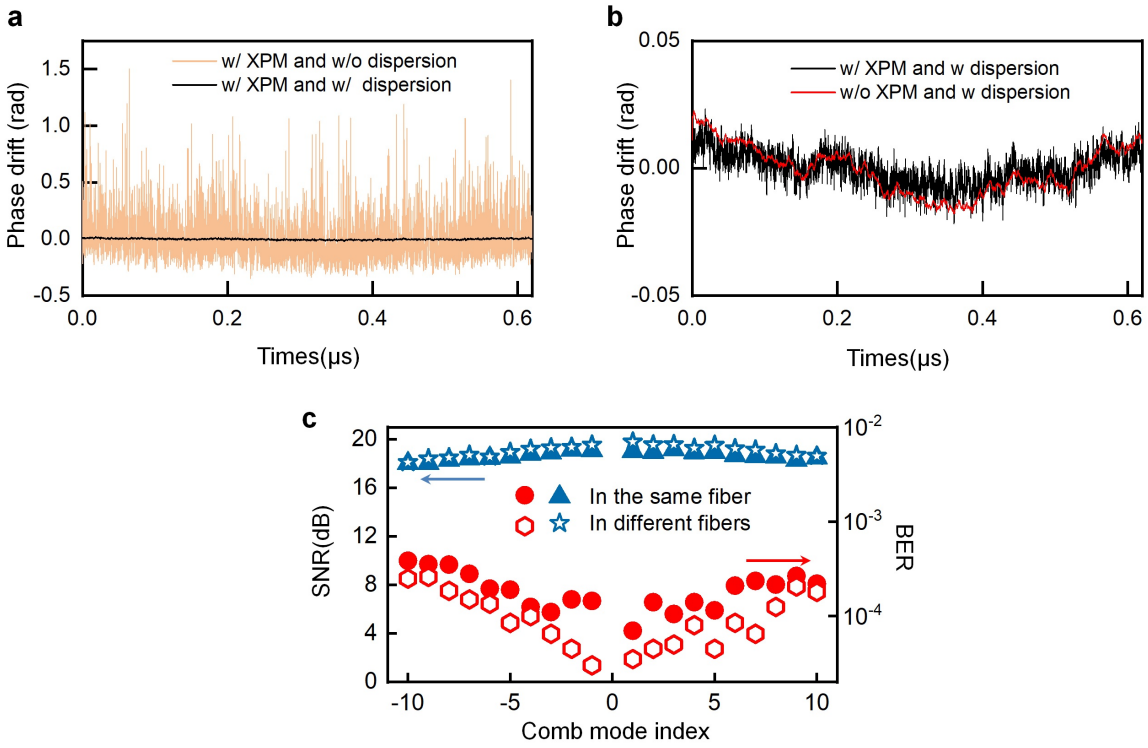

Fig. S1: **Simulation results of phase degradation induced by fiber nonlinearity. a.** Comparison of the phase deterioration by fiber XPM effect between the cases with and without chromatic dispersion. **b.** Comparison of phase deterioration between with and without XPM effect. **c.** Comparison of experimental measured data receiving SNR and BER when 20 data channels and the pump/pilot tones are transmitted in the same fiber or in different fibers.

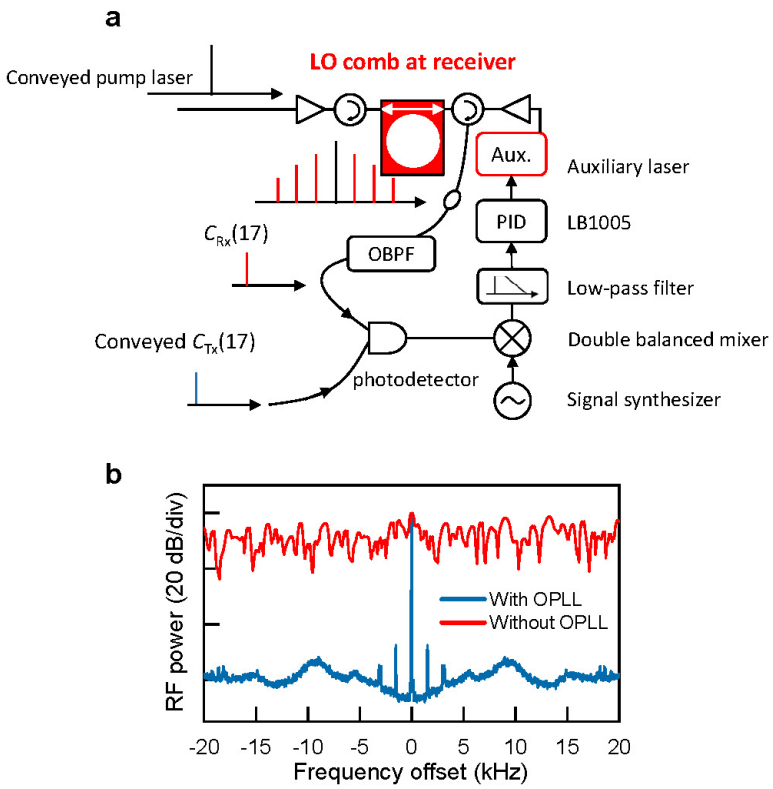

Fig. S2: **a.** Experimental setup of the OPLL for locking of $C_{\mathrm{Tx}}(17)$ and $C_{\mathrm{Rx}}(17)$. **b.** Comparison of the beat notes between $C_{\mathrm{Tx}}(17)$ and $C_{\mathrm{Rx}}(17)$ with and without using OPLL.