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Single Dark-Pulse Kerr Comb Supporting 1.84 Pbit/s Transmission over 37-Core Fiber


1 DTU Fotonik, Technical University of Denmark, Ørestads Plads 341, DK-2800 Kgs. Lyngby, Denmark
2 Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen Ø, Denmark
3 Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg, Sweden.
4 Optical Technologies R&D Center, Fujikura Ltd., 1440, Mutsuzaki, Sakura, Chiba, 285-8550, Japan
asbjørn.arvad@nbi.ku.dk

Abstract: We show that a single dark-pulse Kerr comb can generate high enough OSNR to carry 1.84 Pbit/s data, achieved by 223 WDM spectral lines modulated with 32-Gbaud, SNR-adapted probabilistically shaped DP-QAM, over a 37-core fiber. © 2020 The Authors

Optical frequency combs show potential as sources for future communication systems. The intrinsic relative line stability of the combs can enable joint digital signal processing, which could lead to below zero guard-bands [1], easier phase tracking [2], and improved nonlinear transmission [3]. Furthermore, the large bandwidths of combs have allowed fiber-based comb sources to support data rates of several Pbit/s [4,5]. Nonlinear microring resonator (MRR) based optical frequency combs provide the same advantageous characteristics of traditional combs while maintaining a small footprint and integratability. While two MRRs producing bright soliton combs were used to carry 50 Tbit/s [6], another class of MRRs producing dark-pulse Kerr combs [7] have become attractive due to its 5-10 times larger pump-to-comb conversion efficiency [8], allowing for higher-order data modulation formats [9].

We report on an MRR dark-pulse Kerr comb covering the C+L-bands, with an average OSNR per line of 27 dB in 0.1 nm bandwidth. We use this comb as the source of light to demonstrate 1.84 Pbit/s achieved data rate transmission through a 7.9-km 37-core single-mode fiber, the highest data rate carried by light from a microring comb source.

![Fig. 1](image-url) Fig. 1. (a) The experimental setup, (b) Measured comb power (Orange) and on-chip micro heater output (Red) during a time period where the control servo is switched off after 30 min.

We use a 105.2 GHz free spectral range (FSR) Si$_3$N$_4$ MRR to generate a dark-pulse Kerr comb. The device is fabricated using a novel subtractive processing method [10] and has a mean intrinsic Q of 10.6 million. The width and height of the ring waveguide are 1850 nm and 600 nm, respectively. Its over-coupled design optimizes the conversion efficiency [8] (17% measured for 29 dBm of on-chip coupled power). The measured dispersion is 68 ps/nm/km, designed to maximize the power per line across the available bandwidth [8]. The pump laser is set at 1562.7 nm, close to resonance with a weak mode crossing [10]. The dark pulse Kerr comb is initialized using an on-chip microheater to tune the resonance closer to the pump, i.e. with fixed pump wavelength.

The experimental setup is shown in Fig. 1(a). Leaving the MRR, the comb frequencies are divided into the C and L bands. The pump is filtered away by a short pass filter (SPF), at the cost of 3 spectral lines. An FPGA-based servo uses the microheater to stabilize the optical power in the generated comb lines. This is critical for long term operation as seen in Fig. 1(b) where the optical comb power is plotted together with the micro-heater output. This setup can maintain the comb state for several hours. The line spacing stability is measured by electrooptic downconversion and
achieve and the measured RF
Fig. 2. (a) Optical spectra of the simulation (red) and the measured dark-pulse Kerr comb (blue). Insets show the simulated time-domain pulse profile and the measured RF beat spectrum of the comb from DC to 10 GHz; (b) Optical spectrum (brown) of the 35-GHz modulated comb with measured OSNR of each line (black); (c) Achieved bit rate in bit per symbol per fiber-core, after FEC decoding with error-free performance. All 37 cores achieve the same data rate for each channel by design. Insets are representative probabilistically shaped constellation maps for the received 256- and 64-QAM signals.

Figure 2(a) shows the spectrum of the comb. The insets show the simulated time-domain profile and the measured RF amplitude noise spectrum, both confirming mode-locking of the comb. The final output spectrum of our source is depicted in Fig. 2(b) together with the OSNR measured before the first circulator. Figure 2(c) shows the experimentally achieved bit rate in terms of bit per symbol per core. Each point represents 37 cores as they were all tested with identical bit rates based on the tailored shaping. The two insets are representative probabilistically shaped constellations for the received 256- and 64-QAM signals. The performance degradation in the lower C band is due to the EDFA gain shape limitation. The performance variation in the L band comes from the instabilities of the L-band EDFAs used in this experiment. In all, 121 channels in the C band (6 channels of 64 QAM and 115 of 256 QAM) and 102 channels in the L band (64 QAM) are successfully transmitted. The total achieved bit rate excluding the LDPC overhead is 1.93 Pbit/s. A data rate of 1.84 Pbit/s is calculated after subtracting the 4% pilot overhead and the assumed 1% outer FEC overhead used to correct any remaining errors (BER below 10^-5) from the LDPC decoder [16].

We have demonstrated the highest reported data rate carried on the light from a single microring comb source, reaching 1.84 Pbit/s on 223 WDM channels over a 37-core fiber.

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