Optimization of Parametric Comb Generation Using Interferometric Wavelength Selective Switch

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Abstract: We propose and demonstrate frequency comb regeneration using parametric mixer dispersion managed by interferometric wavelength selective switch. The results show a good control over the bandwidth/flatness of the comb generated by the parametric process.

OCIS codes: (190.4380) Nonlinear optics, four-wave mixing; (190.4410) Nonlinear optics, parametric processes.

1. Introduction

Coherent optical transmission and wavelength division multiplexing (WDM) are accepted to be significant technologies to enable capacity expansion of optical communication systems by enabling higher order modulation formats, superchannels, and flex-grid WDM. To achieve performance stability of coherent higher order modulation formats, the operator should deploy local oscillator (LO) lasers that have low linewidth, low relative intensity noise (RIN), low spectral and phase instability in WDM grid lines. Optical frequency combs have been proposed as LO source in optical transmission systems [1] to achieve system-wide coherency (that can allow full-field digital backpropagation [2]) and reduce deployed recourses in the systems (i.e. using single comb source instead of dedicated laser for each WDM channel). An optical frequency comb should originate from a single, low linewidth, source seed to guarantee phase locking of the generated comb lines. Also, it should realize stable (and preferably flexible) frequency spacing between the generated lines. One way of comb generation is using parametric nonlinear process in optical fiber (namely four wave mixing FWM) [3] seeded by phase locked laser lines, this methodology needs a very careful dispersion engineering through the different stages of mixers to generate flat comb lines (theoretically described in [4]). A pre-engineered dispersion management in multistage parametric comb generator will limit the flexibility of the comb to change the frequency spacing between its lines.

In this paper, we propose and demonstrate the use of interferometric wavelength selective switch (WSS) and a parametric mixer for achieving comb regeneration, showing that the WSS can provide flexible pre-dispersion management to control the outcome of the parametric process to generate comb. By optimizing the phases of comb source lines (flat 13 lines with 10GHz frequency separation), we have been able to almost triple the number of comb lines (keeping 1dB flatness) generated by a single stage parametric nonlinear mixer.

2. Experimental setup and results

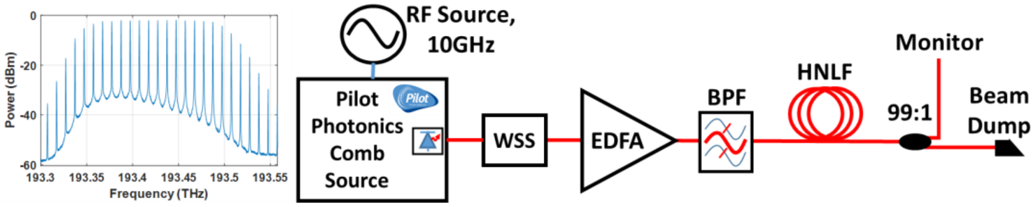

Fig. 1 Parametric comb regeneration: (left) optical spectrum generated by pilot photonics comb source, (right) experimental setup.

In order to evaluate the capabilities of comb regeneration (pre-dispersed by interferometric WSS), we implemented the experimental setup shown in Fig. 1 (right). The seed of the parametric comb regenerator is generated using a Pilot photonics comb source [5] centered at 1550nm. The seed consists of 13 lines (separated by 10GHz) with 1dB of power variation (Fig. 1 (left)). Next a programmable/interferometric WSS with a resolution of 1GHz is used to control the phases of output comb lines to emulate dispersion. The output of WSS is amplified by high power EDFA to 33dBm and filtered by a band pass filter (BPF) to eliminate the out-of-band amplified spontaneous emission (ASE) noise generated by the EDFA. The filtered 13 comb lines (with a total power of 31.5dBm) are propagated through a 70m highly nonlinear fiber (HNLF) that has a zero dispersion wavelength (ZDF) at 1551nm, nonlinear factor of 21.4$(W.km)^{-1}$, dispersion slope of 0.043 $ps/nm^2/km$, stimulated Brillouin scattering (SBS) threshold of 22dBm. The regenerated comb (at the output of HNLF) was monitored, at 1% output, by 150MHz resolution optical spectrum analyzer (OSA).

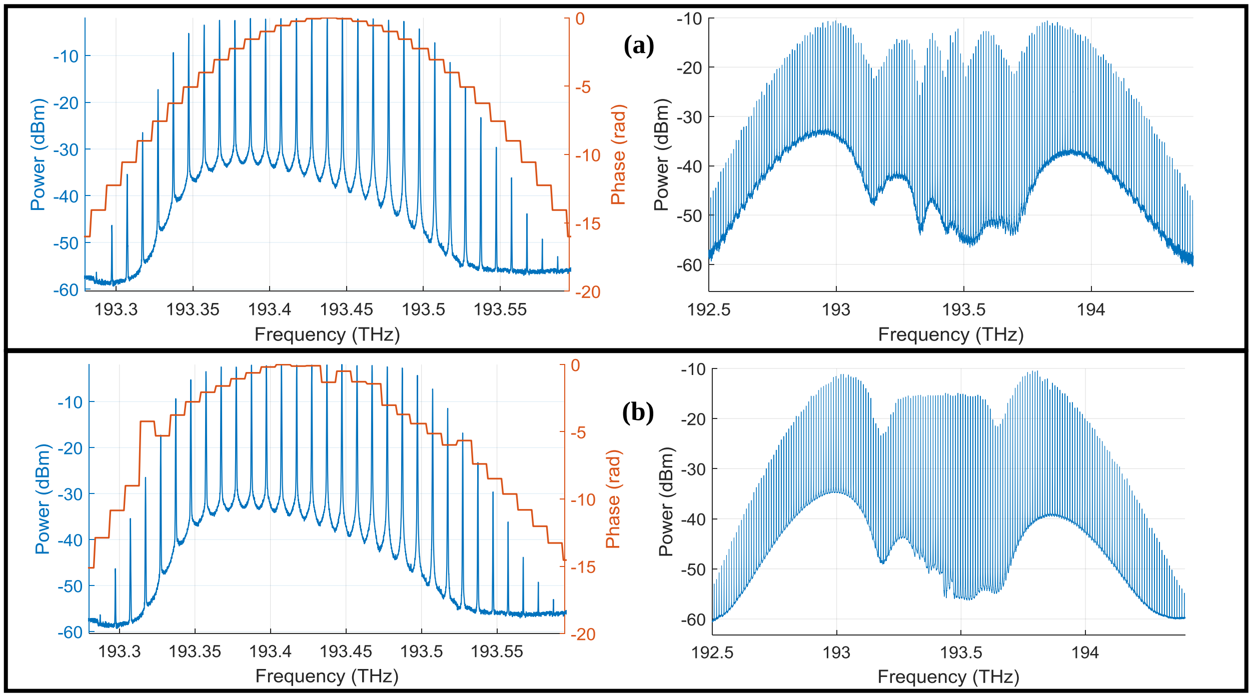

Fig. 2 (a) left plot shows that comb source output and the phase profile applied to its lines by WSS, the right plot shows the regenerated comb at the output of HNLF. (b) left plot shows that comb source output and the phase profile applied to its lines by WSS, the right plot shows the regenerated comb at the output of HNLF.

As we have applied an equivalent of -25ps/nm dispersion to the source comb lines (see fig. 2(a)), we have seen that the comb lines will be regenerated to spread over 1.4THz with power variation of 14dB and a line extinction ratio ranging from 25dB to 38dB (source extinction ratio ranges from 28dB to 44dB for comparison). By optimizing the individual phases of comb source lines to achieve the 1 dB flatness in regenerated comb (see fig. 2(b)), we were able to achieve 38 lines (380 GHz bandwidth /10GHz spacing) and line extinction ratio ranging from 26dB to 40dB. From fig. 2 (a & b), it can be seen that the side lopes of the regenerated comb cannot be eliminated since they are resulted from higher order FWM resulted at a phase mismatching state according to the local dispersion of the HNLF (due to the high dispersion slope of our fiber). The parametric ASE noise (modulation instability) floor variation between the side lopes can be explained by the fact that lower frequency side lope is resulted from the FWM at normal HNLF local dispersion (D>0), while the higher frequency side lope is resulted from the FWM at negative HNLF local dispersion (D<0)[4].

3. Conclusion

We experimentally demonstrated that introducing an interferometric WSS pre-dispersing comb seed lines can flexibly change parametric nonlinear interaction in an optical mixer medium. The experiment conducted in this work, shows that the number of regenerated comb lines can be, at least, triple the bandwidth of a seed comb source with a restricted requirement of power flatness.

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4. References

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