Microcomb-based RF transversal filters

Xingyuan Xu,¹ Mengxi Tan,¹ Jiayang Wu,¹ Thach G. Nguyen,² Sai T. Chu,³ Brent E. Little,⁴ Roberto Morandotti,^{5,6,7} Arnan Mitchell,² and David J. Moss^{1,*}

¹Centre for Micro-Photonics, Swinburne University of Technology, Hawthorn, VIC 3122, Australia

²ARC Centre of Excellence for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), RMIT University, Melbourne, VIC 3001, Australia

³Department of Physics and Material Science, City University of Hong Kong, Tat Chee Avenue, Hong Kong, China.

⁴State Key Laboratory of Transient Optics and Photonics, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Science, Xi'an, China.

⁵INRS-Énergie, Matériaux et Télécommunications, 1650 Boulevard Lionel-Boulet, Varennes, Québec, J3X 1S2, Canada.

⁶National Research University of Information Technologies, Mechanics and Optics, St. Petersburg, Russia.

⁷Institute of Fundamental and Frontier Sciences, University of Electronic Science and Technology of China, Chengdu 610054, China.

*dmoss@swin.edu.au

Abstract: We demonstrate high-Q RF filters based on a 49GHz-FSR integrated microcomb source that provides 80 wavelengths across the C-band. A Q factor of 73.7 and an out-of-band rejection of 48.9 dB are demonstrated.

1. Introduction

RF filters are one of the basic and most commonly used components in modern electronic systems [1-3]. While electronic approaches are limited by the “electrical bottleneck” [4], photonic RF filters offer greater performance and many other advantages. Transversal photonic RF filters [5-10] generate weighted and progressively delayed replicas of an input RF signal in the optical domain and then combine them together upon photo-detection. They are capable of achieving arbitrary RF transfer functions by simply changing the tap weights, and are thus an attractive because of their extreme versatility. In this paper, we demonstrate a micro-comb [11] based photonic RF transversal filter with a record high number of taps consisting of 80 wavelengths over the C-band. This resulted in a Q_{RF} factor for the RF bandpass filter four times higher than previous results [12]. Further, by programming and shaping the Kerr optical micro-comb, we achieve RF filters with a high out-of-band rejection of up to 48.9 dB using Gaussian apodization. Our experimental results agree well with theory, verifying the feasibility of our approach towards the realization of high performance advanced adaptive RF transversal filters with potentially reduced cost, footprint, and complexity.

2. Theory and Experimental results

Fig. 1. Schematic diagram of the transversal RF filter based on microcombs. TLS: tunable laser source. EDFA: erbium-doped fibre amplifier. PC: polarization controller. BPF: optical bandpass filter. TCS: temperature controller stage. MZM: Mach-Zehnder modulator. SMF: single mode fibre. PD: photodetector.

Figure 1 shows a schematic diagram of the 80-tap transversal filter based on micro-combs. The soliton crystal comb was then spectrally shaped via a two-stage optical spectral shaper (Finisar, Waveshaper 4000S) in order to enable a larger dynamic range for the comb shape and higher shaping accuracy than a single stage [7]. The shaped comb lines were then fed into a dual input optical Mach-Zehnder modulator (MZM) biased at quadrature to yield both positive and negative taps, and then through ~5-km of standard single mode fibre (SMF) to provide the progressive tap delays. The dispersion of the SMF was ~17.4 ps / (nm · km), corresponding to a time delay T of ~34.8 ps between adjacent taps, yielding an FSR_{RF} of ~28.73 GHz for the transversal filter.

To demonstrate the Q_{RF} factor enhancement brought about by the microcomb’s large number of wavelengths, we implemented a low-pass sinc filter (i.e., $h_{sinc}(n)=1$) with different numbers of taps. The 3-dB bandwidth (BW_{sinc}) was measured to calculate the corresponding Q_{RF} factor ($Q_{RF} = BW_{sinc} / FSR_{RF}$). The RF transmission spectra of the sinc

filter (Fig. 3(b)), measured by a vector network analyser (VNA, Anritsu 37369A), showed good agreement with theory (Fig. 3(a)). The measured BW_{sinc} decreased from 3.962 to 0.236 GHz when the tap number was increased from 2 to 80, indicating a greatly enhanced Q_{RF} of up to 73.7 with 80 taps.

Fig. 2. (a) Calculated relationship between Q_{RF} factor and the number of taps. (b) RF transmission spectra of the sinc filter. (c) Optical and (d) RF transmission spectra of the Gaussian-apodized sinc filter. (e) Optical and (f) RF transmission spectra of the centre-frequency-tunable filter.

To improve the out-of-band rejection of the transversal filter, a Gaussian apodization was applied to the sinc filter, with a main-to-secondary sidelobe ratio of up to 48.9 dB (Fig. 3(c, d)). In order to demonstrate the tunability of the 80-tap transversal filter's centre frequency, the tap coefficients of the Gaussian-apodized sinc filter were multiplied by a sine function to shift the RF transmission spectrum. The corresponding RF transmission spectra (Fig. 3(f)) shows a tunable centre frequency ranging from $0.05 \times FSR_{\text{RF}} = 1.4$ GHz to $0.40 \times FSR_{\text{RF}} = 11.5$ GHz with a relatively high MSSR of >25 dB, occupying 90% of the Nyquist band.

3. Conclusion

We demonstrate a microcomb-based photonic RF transversal filters with 80 taps over the C-band. We achieve Q_{RF} factors that are four times larger than previously demonstrated, as well as a high out-of-band rejection of up to 48.9 dB using Gaussian apodization. The experimental results agree well with theory, verifying that our transversal filter is a competitive approach towards achieving advanced adaptive RF transversal filters with broad operational bandwidths, high frequency selectivity, high reconfigurability, and potentially reduced cost and footprint, all of which are critical issues for modern communications systems.

4. References

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