High Q RF transversal filters based on an 80-channel integrated soliton crystal microcomb source

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ABSTRACT

We demonstrate a high-Q RF transversal filter based on a 49GHz-FSR integrated microcomb source that provides 80 taps across the C-band. By employing an on-chip micro-ring resonator, we generate a broadband Kerr comb with a large number of comb lines and use it as a high-quality multi-wavelength source. A Q factor of 73.7, an out-of-band rejection of 48.9 dB, and a wide tunable range are demonstrated. The experimental results verify the feasibility of our approach as a solution towards implementing highly reconfigurable MPFs with a large tap number and reduced system complexity.

Keywords: Radio frequency photonics, nonlinear optics, integrated optics

1. INTRODUCTION

Driven by the ever-increasing demands of broader operation bandwidth, higher frequency selectivity, and lower cost, advanced RF filters are widely researched for applications in modern communication systems [1-3]. While electronic approaches are limited by the “electrical bottleneck”, photonic RF filters offer greater performance and many other advantages. Transversal photonic RF filters [4-6] are attractive approaches since they are capable of achieving arbitrary RF transfer functions by simply changing the tap weights. Traditional approaches, including those based on discrete laser arrays or optical frequency comb sources, suffer from drawbacks in one form or another, such as the increased cost and size or the need of high-frequency RF sources. In this paper, we demonstrate a micro-comb based photonic RF transversal filter with a record high number of taps consisting of 80 wavelengths over the C-band. This is the highest number so far reported for microcomb-based RF transversal filters, enabled by a 49GHz-free-spectral-range integrated Kerr micro-comb source [7-10]. This resulted in a Q_{RF} factor for the RF bandpass filter four times higher than previous results. 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 and a wide tunable range. 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 for a wide range of microwave functions [11-27].

2. EXPERIMENTAL DEMONSTRATIONS

Figure 1(a) shows a schematic diagram of the 80-tap transversal filter based on micro-combs. To generate Kerr micro-combs, the pump power was set at ~30.5 dBm and the wavelength was swept from blue to red. As the detuning was changed further, distinctive soliton crystal optical spectra were generated. The soliton crystal comb was then spectrally shaped via a two-stage optical spectral shaper (Finisar, Waveshaper 4000S). 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.

To demonstrate the enhancement in the Q_{RF} factor, we shaped the micro-comb to implement a low-pass sinc filter featuring equal tap weights for different numbers of taps ranging from 2 to 80 and measured the 3-dB bandwidth (BW_{sinc}) to calculate the corresponding Q_{RF} factor ($Q_{RF} = FSR_{RF} / BW_{sinc}$). As shown in Fig. 1(b), 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. To improve the performance of the transversal filter in terms of out-of-band rejection, Gaussian apodization was applied to the sinc filter (Fig. 1(c)). As a function of decreasing root mean square width of the Gaussian function σ , the main-to-secondary sidelobe ratio of the sinc filter increased from 26.4 to 48.9 dB. 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 in Fig. 1 (d) shows a tunable centre frequency ranging from $0.05 \times FSR_{RF} = 1.4$ GHz to $0.40 \times FSR_{RF} = 11.5$ GHz with a relatively high MSSR of >25 dB.

In conclusion, we demonstrate a microcomb-based photonic RF transversal filters with 80 taps. The experimental results agree well with theory, verifying that our transversal filter is a competitive approach towards achieving advanced adaptive RF transversal filters.

Fig. 1. (a) schematic diagram of the 80-tap photonic RF transversal filter. EDFA: erbium-doped fiber amplifier. PC: polarization controller. PD: photodetector. VNA: vector network analyzer. RF transmission spectra of (b) the sinc filter with different tap numbers, (c) the Gaussian-apodized sinc filter, and (d) tunable bandpass filter.

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