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Kerr Micro-combs for Radio Frequency Photonics -INVITED

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***Abstract*— We review applications of Kerr micro-combs in RF photonic systems including fractional differentiators, Hilbert Transformers and many other functions.**

Radio frequency (RF) and microwave photonics, which bring together the worlds of radiofrequency engineering and optoelectronics [1], exploit the potential of optical technologies and benefit RF systems in many respects, including high speed, broad operation bandwidth, low loss, and strong immunity to electromagnetic interference [2-4]. A diverse range of photonic approaches to RF signal generation, transmission, processing, and sensing have been proposed and widely employed in RF systems and communication networks [5-13]. Nevertheless, most RF systems are composed of discrete components, which impose certain drawbacks in terms of cost, power consumption and reliability, thus holding RF photonic systems from reaching maturity and replacing traditional RF solutions [14, 15]. Meanwhile, advances in integrated photonics [16-21], driven by the compelling economics of ever smaller footprint and lower power consumption, have created new possibilities and opportunities for RF photonics. Commercialized wafer scale fabrication of III-V, dielectrics, elemental semiconductor and nonlinear crystals have solved key challenges for the co-integration of lasers, modulators, photodetectors, and passive components, and have paved the road for integrated RF photonics to bring it closer towards commercial applications.

We review our recent work on RF and microwave photonic applications of integrated micro-combs, including a reconfigurable RF photonic intensity differentiator, RF channelizer and others. By employing an on-chip nonlinear micro-ring resonator (MRR), we generate a broadband Kerr comb based on soliton crystals, with a record low FSR of 49GHz, generating a large number of comb lines and use it as a high-quality multi-wavelength source for a transversal differentiator. By programming and shaping the power of individual comb lines according to corresponding tap weights, reconfigurable intensity differentiators with variable differentiation orders can be achieved. Detailed analyses of the operation principle and experimental demonstrations of fractional, 1st, 2nd, and 3rd order differentiations are performed.

As one of the most powerful tools in RF photonic systems, optical frequency combs can serve as multi-wavelength sources and establish multiple RF channels, and thus can greatly increase the capacity for transmission and performance for transversal processers [22-26]. Unfortunately, traditional approaches like discrete laser arrays, mode-locked lasers, or cascaded modulators all have limitations of one form or another, such as the cost, ability to be integrated or the number of available wavelengths, and thus pose challenges for integrated RF photonic systems.

Micro-comb sources, particularly those based on novel CMOS-compatible platforms [27, 28], offer new possibilities for integrated RF photonics. In 2008-10, new platforms for nonlinear optics, including Hydex [27, 29-36] and silicon nitride [37], were introduced that exhibit negligible nonlinear absorption in the telecom band, a moderate nonlinear parameter and extremely high nonlinear figure of merit, which are ideal for micro-comb generation. Following the first report of Kerr frequency comb sources in 2007 [38], the first integrated CMOS compatible integrated optical parametric oscillators were reported in 2010 [27, 37], and since then this field has exploded. Many cutting-edge applications have been demonstrated based on CMOS-compatible micro-combs, ranging from filter-driven mode-locked lasers [39-42] to quantum physics [43-48]. Meanwhile, for RF photonics, many new applications have been investigated with the fundamental advantages of micro-combs demonstrated [49-51].

As compared with conventional intensity differentiators based on laser diode arrays, the cost, size and complexity can be greatly reduced. Our scheme enables a high degree of reconfigurability in terms of processing functions and operation bandwidth, offering a reconfigurable platform for diverse microwave photonic computing functions. By programming the waveshaper's tap coefficients, our scheme can also apply to other computing functions such as Hilbert transforms. The operation bandwidth is fundamentally limited by the Nyquist zone, which is determined by the comb spacing. In our case, the frequency spacing of the Kerr comb generated by the nonlinear MRR reaches 200 GHz, thus leading to a potential operation bandwidth of over 100 GHz.

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