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Simultaneous multi-channel microwave photonic signal processing

Lawrence R. Chen
Department of Electrical and Computer Engineering, McGill University, Montreal, QC H3A 0E9 Canada

Microwave photonic (MWP) systems exploit the advantages of photonics, especially with regards to ultrabroad bandwidth, adaptability, and parallelism, features that are significantly more challenging to obtain in the electronic domain. Thus, MWP systems can be used to realize a number of microwave signal processing functions including, amongst others, waveform generation, and radio-frequency spectral analysis (RFSA). In this paper, we review recent results on fiber and integrated approaches for simultaneous generation of multiple chirped microwave pulses (CMPs) as well as multi-channel RFSA of ultrahigh repetition optical rate pulse trains.

CMPs have been used widely in various applications, including communications, sensing, and instrumentation. Photonic generation of CMPs offers the possibility of achieving central frequencies of tens to hundreds of GHz as well as significant chirp rates, thereby supporting tens of GHz of bandwidth. Photonic approaches also provide increased flexibility, especially in terms of tunability and reconfigurabilty. A popular approach for photonic generation of CMPs involves optical spectral shaping followed by wavelength-to-time mapping (as a means to synthesize the desired temporal waveform prior to photodetection). Most implementations demonstrated to date are capable of only generating a single CMP (i.e., of specific central frequency or chirp rate) at a time. The ability to generate simultaneously multiple CMPs with different characteristics may enhance flexibility and capability in instrumentation and imaging applications. We describe two fiber-based implementations for simultaneous generation of multiple (at least two) CMPs. The first approach uses superimposed linearly chirped fiber Bragg gratings (LCFBGs) in a Sagnac loop while the second incorporates multiple identical LCFBGs in an arrayed waveguide Sagnac interferometer. We show how these structures can be used to synthesize multiple CMPs with the same central frequency and different chirp rates, as well as to obtain independent control over the central frequency and chirp rate of the CMPs.

RFSA is widely used for RF spectral characterization of photonically generated ultrabroadband RF arbitrary waveforms and ultrahigh repetition rate optical pulse trains. By exploiting ultrafast nonlinear optics (e.g., Kerr effects), photonic implementations of RFSA allow for processing optical signals with a bandwidth well beyond 100 GHz. Photonic RFSA has been reported using integrated technologies in silica, silicon-on-insulator, and chalcogenide material platforms. In all demonstrations, however, only a single channel can be characterized at a time. Simultaneous multi-channel simultaneous RFSA within one single integrated device is more practical since concurrent operation for various optical sources helps reduce the number of the nonlinear waveguides in the single-channel RFSA scenario. Integrated waveguides can be engineered to support a few propagating spatial modes which we can make use of to enable simultaneous multi-channel RFSA. This creates a new degree of freedom for scaling the number of channels that can be monitored and/or characterized simultaneously. We demonstrate how to harness mode-selective excitation of nonlinear optics in an integrated silicon photonic device to realize on-chip multi-channel RFSA.