Dispersive Fourier Transformation for Microwave Photonics Applications

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Abstract— Dispersive Fourier transformation (DFT) maps the broadband spectrum of an optical pulse into a time stretched waveform using chromatic dispersion [1]. Owing to its capability of real-time pulse-by-pulse spectroscopic measurement and manipulation, DFT has become an emerging technique for ultrafast signal generation and continuous single-shot measurements in optical communications, optical sensing, spectroscopy and imaging, where the speed of traditional instruments falls short [2].

In this paper, the principle and implementation methods of DFT are introduced and its widespread applications in microwave photonics systems are presented. The most obvious and straightforward application of DFT is real-time spectroscopy, where the instantaneous spectral characteristics of an ultrashort optical pulse are encoded onto its temporal intensity variation. Fast dynamic phenomena that are encoded onto the optical spectrum can be now acquired and slowed down in the time domain so that they can be digitized and analyzed in real-time. Compared to traditional optical spectroscopy instruments, DFT-based real-time spectroscopy offers a few orders of magnitude higher measurement speed. As two examples of ultrafast real-time spectroscopy, ultrafast gas absorption spectroscopy [3] and fiber Bragg grating interrogation [4] are introduced. DFT technique can also be applied in photonic-assisted microwave arbitrary waveform generation [5], where the spectrum of the optical pulse is manipulated on purpose using an optical spectral shaper. By properly designing the response of the spectral shaper, a microwave waveform with its shape identical to that of the shaped optical spectrum can be produced [6–9]. In another application of DFT, due to the one-to-one mapping relation between spectrum and time, the spectrum shape of the pulse can be changed in a fast and reconfigurable manner using temporal modulation — a technique called time-domain spectral shaping. One example of this technique is instantaneous microwave frequency identification based on temporal channelization [10]. The final microwave photonics application of DFT technique is ultrafast real-time imaging [11], which is made possible by employing additional spatial dispersion to encode the spatial information (image) onto the pulse spectrum. The images can then be reconstructed from the temporally stretched optical pulses. With its capability of fast continuous capturing, DFT-based imaging technique is expected to be useful for high-throughput screening of rare objects or events.

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