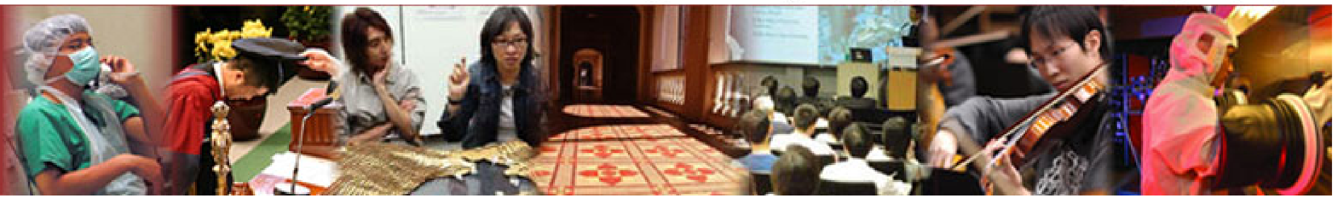

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Fast Swept-Source Generation Based on Fiber Optical Parametric Amplifier

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Abstract: We experimentally demonstrate a fast frequency swept-source using the dispersive Fourier transformation-based fiber optical parametric amplifier. The swept rate is as high as 78 MHz, with a linewidth of 0.135 nm.

OCIS codes: (060.2320) Fiber optics amplifiers and oscillators; (060.4370) Nonlinear optics, fibers; (190.4410) Nonlinear optics, parametric processes.

1. Introduction

Fast frequency swept-sources play important roles in high-speed optical imaging and spectroscopy, such as serial time-encoded amplified microscopy (STEAM), swept-source optical coherence tomography (SS-OCT), and real-time spectroscopy [1, 2]. Conventional swept-sources are achieved based on various cavity configurations. However, the swept speed in such configurations is fundamentally limited by the cavity lifetime, which is inversely proportional to the linewidth of the swept-source [3]. In view of this constraint, we here introduce a high-speed cavity-free swept-source generated by a novel fiber optical parametric amplifier (FOPA) in which an ultrafast swept pump is realized by a technique called dispersive Fourier transformation (DFT) [4, 5].

In this paper, we experimentally demonstrate a bandwidth-doubled idler with respect to the pump with an ultrafast swept rate of 78 MHz and a linewidth of 0.135 nm. Such all-optical approach offers orders-of-magnitude higher swept rate and thus lends itself to many applications such as high-speed signal processing and optical imaging.

2. Experiment and Results

The experimental setup of the swept pump generation is shown in Fig. 1 (a). A 78 MHz picosecond pulse source (peak power: $22W$) entered into a 50-m highly-nonlinear dispersion-shifted fiber (HNL-DSF) (γ =14 $W^{-1}km^{-1}$, λ_0 =1554.7 nm) to generate supercontinuum (SC). We also added a weak continuous-wave (CW) light (at 1610 nm) to further enhance the generation of SC and to improve the stability of SC. Here, a 50-km single-mode fiber (SMF) introduced a linear down chirp for the DFT procedure. Figure 1 (b) shows the configuration of the swept pump FOPA, and the swept-source was combined with a CW or pulsed signal into another 1-km HNL-DSF (γ =14 $W^{-1}km^{-1}$, λ_0 =1561 nm). As a result, a high-speed, bandwidth doubled, frequency-swept idler was then generated by such swept pump FOPA. The swept-source linewidth measurement was illustrated in Fig. 1 (c), corresponding to the two

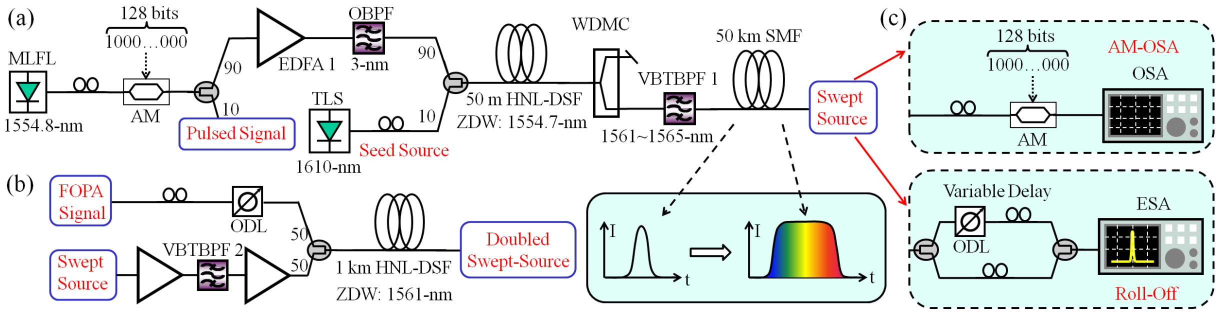

Fig. 1. Experimental setup: (a) the fast swept-source generation by the DFT process; (b) the swept pump FOPA procedure to achieve a doubled wavelength swept range; (c) the linewidth measurement of swept-source: AM-OSA method (upper) and Roll-off method (lower). MLFL: mode-lock fiber laser; AM: amplitude modulator; OBPF: optical bandpass filter; WDMC: wavelength-division multiplexing coupler; VBTBPF: variable bandwidth tunable bandpass filter; ODL: optical delay line; OSA: optical spectrum analyzer; ESA: electrical spectrum analyzer.

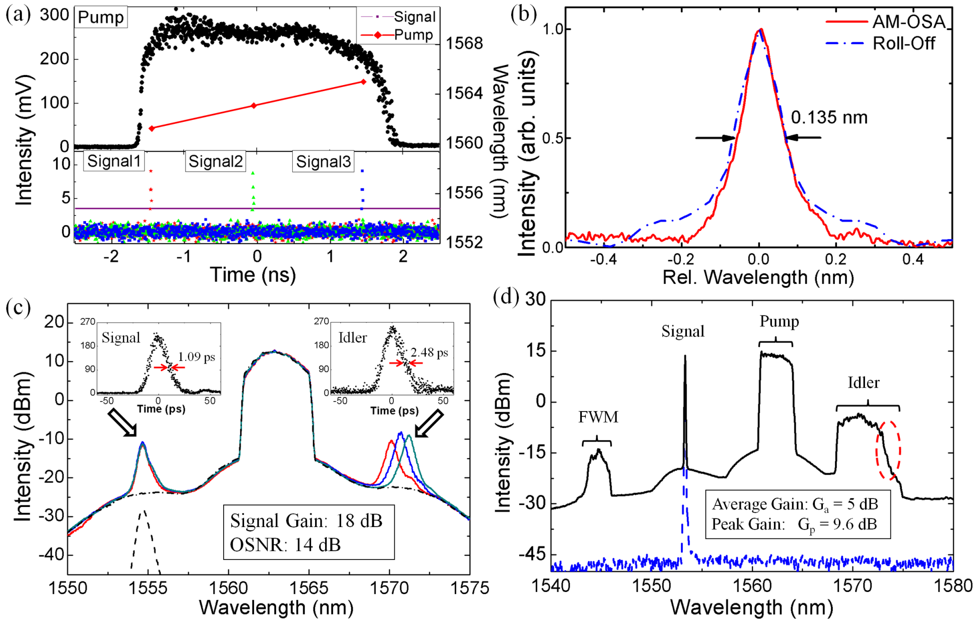

Fig. 2. Experimental results: (a) the temporal waveform of the swept pump and the mapping between wavelength and time; (b) linewidth measurement results obtained from the AM-OSA and roll-off methods; (c) the FOPA spectra with the pulsed signals at different time instant. Insets: the amplified signal and idler waveforms; (d) the FOPA spectra with CW signal.

methods compared in reference [6], the AM-OSA method employed the AM as fast optical shutter (about 150 ps) to select certain time slot, and the result could be regarded as an instantaneous linewidth; while the conventional roll-off measurement was for the average of the whole swept range, and Fourier transformation can derive the linewidth trace.

The temporal waveform of the swept pump is shown in Fig. 2 (a), and the 3.4-ns pulsewidth matches well with the calculation, while the inside wavelength information is obtained from the degenerate four-wave mixing (FWM) relation. The ultrahigh swept speed is 4 nm/3.4 ns (150 THz/μs), and 100-fold faster than the cavity reconfigurations, which also makes the linewidth measurement difficult. Figure 2 (b) shows the linewidth of our swept-source is about 0.135 nm, which is applicable in the SS-OCT (less than 0.2 nm) [2]. Figure 2 (c) and (d) show the FOPA spectra with pulsed and CW signals, and in both of the two cases, over 10 dB optical gain are achieved. For pulsed signal, when tuning signal in time domain, wavelength is tunable at the idler's part. For CW signal, idler becomes an 8-nm swept-source, and the drop in the red-shifted side is due to dispersion-induced walk-off delay (about 1.1 ps).

3. Conclusion

Using DFT technology, we can get orders-of-magnitude higher swept rate, from kHz range to 78 MHz, and the 0.135-nm linewidth is comparable with the SS-OCT's case [2]. Continuing through the FOPA, doubled wavelength range (8 nm) and swept speed are achieved in the idler's part. In addition, the cascaded n-stage FOPA can be employed to scale up the output swept range by a factor of 2^n [3], which could be applied in ultrafast broadband optical imaging.

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