Real Time Amplitude Noise and Jitter Comparison of Supercontinua Generated at Different Dispersion Regimes

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Abstract: An experimental investigation on noise performances of supercontinua generated in normal and anomalous dispersion fibers is carried out. The supercontinuum in the normal dispersion fiber has lower real time amplitude noise and timing jitter.

OCIS codes: (060.2310)Fiber optics; (060.4510)Optical communications; (060.4370) nonlinear optics, fibers

1. Introduction

Because of their enormous potential applications in diverse fields such as optical communication, optical coherent tomography, microwave photonics, optical metrology and sensing, optical-fiber based supercontinuum sources have been studied intensively in the recent years [1-3]. Now the physics underlying supercontinuum generation is generally well understood, and the development of ultrashort pulse lasers and highly nonlinear specialty fibers (such as photonic crystal fibers, tapered fibers and dispersion-shifted fibers) enabled us generate broadband supercontinuum easily. However, most of the supercontinuum sources demonstrated have the problems such as lack of spectral flatness, large noise, polarization sensitivity and so on. In addition, supercontinuum generation in optical fibers based on short pulse lasers also exhibits short pulse characteristics in the time domain, and the considerable noise could be a limiting factor for practical applications. Recently, fundamental noise limitations, phase noise and timing jitter of supercontinuum generation in fibers have been analyzed and numerically investigated [4-6]. However, for applications in microwave photonics, real time amplitude variations and timing jitter have more profound effect than the spectral uniformity.

In this paper, we present experimental comparison of real time amplitude noise and timing jitter of supercontinuum generated in the normal dispersion regime and the anomalous dispersion regime optical sampling applications.

2. Experimental results

The measurements are conducted on supercontinuum generated in normal dispersion regime and spectral broadening induced by soliton effect pulse compression in anomalous dispersion regime. We use 500fs pulses generated by a 3mW modelocked fiber lasers at 1540nm with 20MHz repetition rates as a source. A Low dispersion DSF fiber with λ_0 =1600nm as used as the continuum fiber in normal dispersion regime. In order to generate soliton effect pulse compression, the same laser output is amplified to generate high order solitons and launched into single mode fiber. The bandwidth of the generated supercontinuum is measured to be >40nm @10dB level in normal dispersion regime and extends >100nm in anomalous dispersion regime at high input power levels. Gain in amplifiers is adjusted accordingly to provide similar power spectral densities in two dispersion regimes. Polarization controllers are inserted to alleviate polarization dependency of the supercontinuum and provide stable spectral broadening. A 1nm tunable bandpass filter is used to slice supercontinuum for timing jitter and amplitude noise comparison.

Fig. 1 illustrates the timing jitter distribution of the carved supercontinua between 1535nm and 1560nm. The timing jitter is calculated at 270^{th} harmonic, at 5.4GHz, by using an RF spectrum analyzer [7-8]. We first measure the timing jitter σ_{J-P} (176 fs) of the pump laser, and then measure the timing jitter σ_J at different wavelength of the supercontinuum, as shown in Fig.1. We show that the timing jitter of the supercontinuum generated in normal dispersion fiber closely follows the timing jitter of the pump laser and the total degradation is <2x. The largest timing jitter degradation is measured at the tails of the continuum source where power spectral density >5dB lower than the middle section. The timing jitter at anomalous regime increases by 20x due to delicate interplay between the nonlinear phase shift and the group velocity dispersion [4-6].

The amplitude noise characteristics of supercontinuum sources are studied experimentally by using RF spectrum analyzers. However, the applications such as microwave photonics ultimately rely on real time pulse to pulse amplitude variations. Here, we focus on how amplitude varies in real time to assess their impact on optical sampling. Fig.2 and Fig.3 illustrated the real time measurement of the pulse fluctuations in normal dispersion regime and anomalous dispersion regime, respectively. The results are taken by a 20GSa/s real time oscilloscope with 8GHz

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analog bandwidth. A 750MHz RF filter is inserted before the oscilloscope to eliminate sampling errors. Amplitude statistics are generated based on peak voltages of each trace. The amplitude noise in normal dispersion regime is calculated to be 1% across the 30nm optical bandwidth. The variance of the amplitude noise is measured to be 29.5 mV at 2.69 V level. The variance of the oscilloscope background noise is measured to be 17 mV. The same amplitude noise measurement increases up to 30% at specific wavelengths for the supercontinuum at anomalous dispersion regime and varies between 10% and 30%, as shown in Fig.4 inset.

Fig. 4 illustrated the amplitude noise measured by RF spectrum analyzers. Due to V^2 dependency, lower noise in RF domain is expected in RF measurements. Similar to real time measurement, the amplitude noise of the supercontinuum in normal dispersion fiber is measured to be within 1%. The noise profile is nominally flat and increases by ~0.5 % at low power spectral density tails. However, the amplitude noise of the anomalous dispersion continuum is above 12.5%.

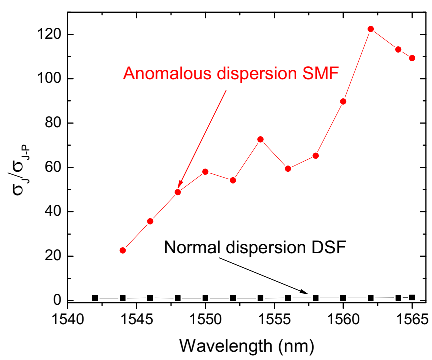

Fig.1 Timing Jitter for supercontinua at different wavelength

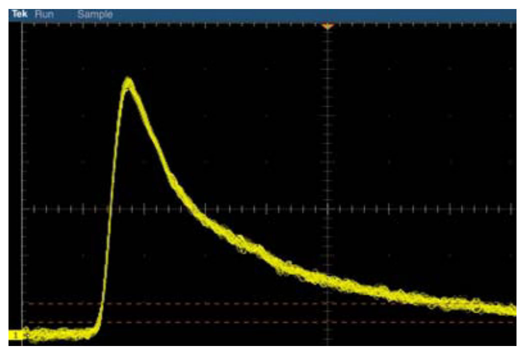

Fig.2 Real time pulse fluctuations in the normal regime.

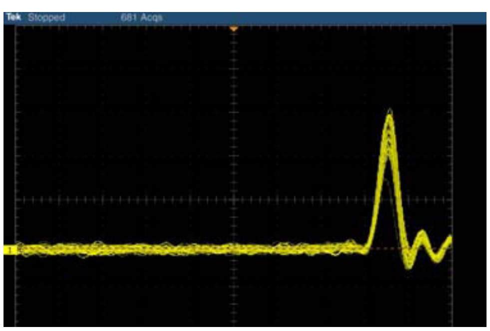

Fig.3 Real time pulse fluctuations in the anomalous regime

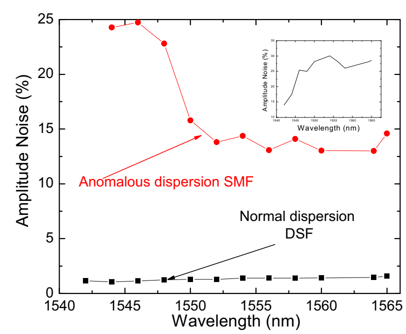

Fig.4 Amplitude noise of supercontinua at different wavelength

3. Summary

The amplitude noise and the timing jitter of the supercontinua generated in DSF and SMF are experimentally investigated, and we show that the supercontinuum generated in the normal dispersion DSF has much lower amplitude noise and timing jitter than that generated in the anomalous dispersion SMF. So the supercontinuum generated in the normal dispersion fiber could be a good solution for some applications those needs low noise broadband sources.

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[1] G. Genty, S. Coen and J.M. Dudley, *J. Opt.Soc. Am. B*, vol. 24, pp. 1771-1784, 2007.
[2] O. Boyraz, J. Kim, M.N. Islam, F. Coppinger and B. Jalali, *J. Lightwave Technol.*, vol.18, pp.2167-2174, 2000.
[3] X. Sang, P. Chu and C. Yu, *Opt. Quantum Electron.*, vol.37, pp.965-994, 2005.
[4] K.L. Corwin, N.R. New Bury, J.M. Duley, S. Coen, S. A. Diddams, K. Weber, and R.S. Windeler, *Phys. Rev. Lett.*, vol.90, pp.113904, 2003.
[5] B.R. Washburn and N.R. Newbury, Opt. Express, vol.12, pp.2166-2175, 2004.
[6] S. Taccheo and k. Ennser, *IEEE Photon Technol. Lett.*, vol.14, no.8, 2002.
[7] D. von der Linde, *Appl. Phys. B*, vol.39, pp.201-217, 1986.
[8] F. Quinlan, S. Gee, S. Ozharar and P.J. Delfyett, *Opt. Lett.,* vol.31, pp.2780-2872, 2006.