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Conversion wavelength and power dependence of an optical delay system utilizing HNLFs and DCF

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ABSTRACT

Conversion wavelength and power dependence of the time delay and output signal quality for an optical delay system consisting of dispersion compensation fiber (DCF) and highly nonlinear fibers (HNLFs) is investigated in this paper. The numerical results show that the time delay generally varies linearly with the conversion wavelength propagating through DCF and changes slightly with the power launched into HNLFs. But it has abrupt change at some values of conversion wavelength or input power level. Output signal quality of the overall system varies significantly with the conversion wavelength and input power level. The reasons behind these results are analyzed. Finally, the input power level is optimized to achieve linearly varying time delay and desirable output signal quality for an optical delay system.

1. Introduction

An all-optical buffer with low signal distortion and controllable time delay of optical packets is desirable for synchronization function requirement or contention resolution [1]. One recently proposed approach uses wavelength conversion and dispersion technique to achieve large time delay, which is based on different wavelength corresponding to different dispersion in a highly dispersive medium [2]. As large as 4.2 ns time delay has been reported to achieve for single one pulse, where the wavelength conversion is realized by the self-phase modulation (SPM) spectrum broadening and filtering technique [3]. However, the pulsewidth was broadened from 3.5 ps to 350 ps by this method, which will result in interpulse interaction and significantly degrade the quality of data signal. To overcome this shortcoming, a 2R regenerative (reshaping and reamplification) optical delay system consisting of highly nonlinear fibers (HNLFs) and dispersion compensation fiber (DCF) has been researched for 10 Gbit/s return-to-zero (RZ) packets [4]. Through controlling signal power level and filtering conversion wavelength, the time delay can be linearly tuned from 0 ps to 170 ps with the wavelength of output signal same as that of input signal, and the regenerative function of the delay system was also demonstrated by the experiment results. Nevertheless, the relationship of the time delay and output signal quality with the conversion wavelength and power level launched into HNLFs is so far seldom comprehensively researched.

In this paper, for the first time to the authors' knowledge, we comprehensively investigate the conversion wavelength and power dependence of the optical delay system from the points of both time delay and output signal quality. To start from the single one pulse, the time delay and output pulse are researched for the optical delay system with different conversion wavelength and optical power launched into the HNLFs. Then the output signal quality of the optical delay system is evaluated by Q factor and eye-diagram for the 10 Gbps RZ data stream. Finally, the power level launched into HNLFs is optimized to achieve the best signal quality for a given conversion wavelength.

2. Operation principle

As in [3], Fig. 1 is the optical delay system researched in this paper. It consists of three stages: wavelength conversion, dispersive delay, and wavelength re-conversion. The optical signal with central wavelength λ_s is amplified by an Erbium-doped fiber amplifier (EDFA), filtered by the 1st optical band-pass filter (OBPF1) and launched into the first span of HNLF1, where the optical spectrum is broadened by the SPM. Then the 2nd optical band-pass filter (OBPF2) with conversion wavelength λ_c is used to select the desired wavelength window. Following the wavelength conversion stage, the signal propagates through the DCF and the time delay is generated, which is proportional to the product of chromatic dispersion of DCF and conversion wavelength shift $\lambda_c - \lambda_s$. After DCF,

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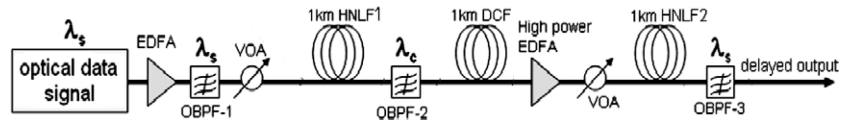

Fig. 1. Optical delay system setup. VOA: variable optical attenuator; OBPF: optical band-pass filter; HNLF: highly nonlinear fiber.

the pulse is amplified by another EDFA and sent through the second span of HNLF2, where the optical spectrum is broadened again. Finally the 3rd optical band-pass filter (OBPF3) centered at λ_s is used to make the delayed output signal have the same wavelength as the original input pulse. The VOAs are used to control the power launched into HNLFs.

For comparison with the reported experimental results, the parameters used in this paper are the same as in [4], where the central wavelength of 10 Gbps optical data signal is 1545.4 nm, the nonlinear coefficient of 1 km HNLF1 is $10.9/(W \cdot km)$, the dispersion coefficient of 1 km DCF is - 67 $ps/(nm \cdot km)$ at 1545.0 nm, and the bandwidth of OBPFs is 0.4 nm.

As in [2–4], the time delay of the overall system is measured by comparing the temporal position of the pulse peak through tuning the center wavelength of OBPF-2. Firstly, we mark down the temporal position of the output signal through tuning center wavelength of the OBPF-2 to λ_s and adjusting VOAs before the HNLFs and DCF for no SPM effect happening. Then we increase the power levels into the HNLFs for exciting the SPM and tune the center wavelength of the OBPF-2 for different time delay. The time difference between the above two cases is so called the time delay of the overall system.

3. Conversion wavelength and power dependence of the time delay and output pulse

At the first stage of the optical delay system, the available conversion wavelength is determined by the SPM-broadened optical spectrum and which part of the broadened spectrum is filtered out. For the simplicity to investigate the time delay, we consider a single pulse as that exploited in [2]. To mimic 10 Gbps RZ data, a Gaussian pulse with full-width at half maximum (FWHM) of 25 ps is used in this part.

It is well known that the SPM-broadened spectrum can be approximately estimated by $\Delta f_{SPM} \sim \Delta f_0 \gamma P_0 L_{eff}$, where Δf_0 and P_0 are spectral width and peak power of the input pulse respectively,

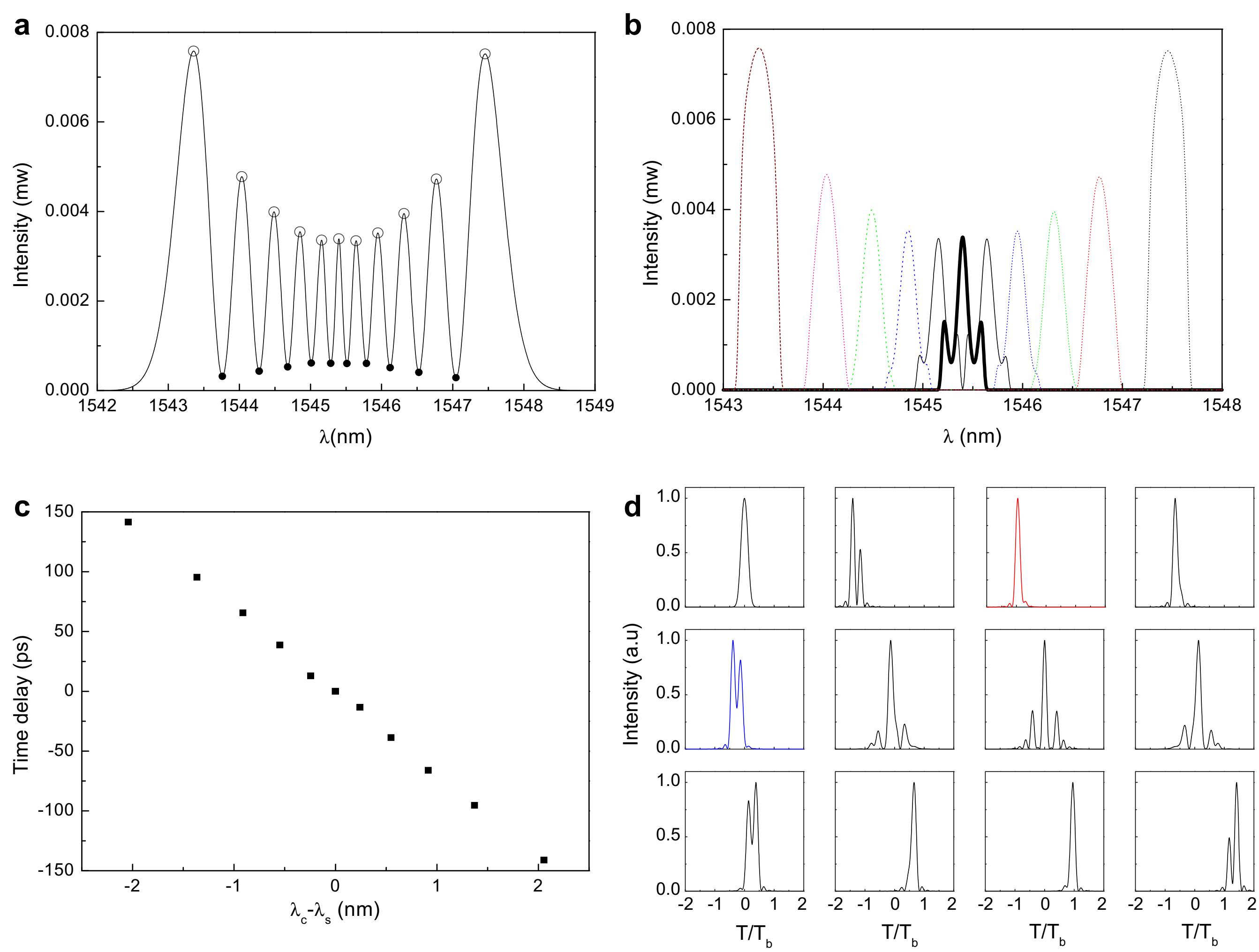

Fig. 2. Conversion wavelength dependence of the time delay and output pulse. (a) SPM-broadened spectrum; (b) Spectrum filtered by OBPF2 centered at respective peak points; (c) Time delay varies linearly with the conversion wavelength shift; (d) Output pulse of the overall system with different conversion wavelength. T_b = 100 ps.